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Comparative study on improvement in Pollen Collection Technology

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Abstract

A newly designed pollen trap for beehives is disclosed. The trap includes a single wooden frame, mounted in the frame are two screens having two meshes (0.5mm in size with 0.7mm distance between them) that are fine enough to dislodge granules of pollen from the bees as they crawl through it. The pollen drops down through the screens into pollen tray. This construction permits the pollen trap to virtually occupy all the area of hive to promote good ventilation for dry pollen. The frame fits in the bottom of the hive by inserting it from back side and can be removed easily when not needed. After designing the new trap a trial was laid down on 11/02/2009 in the premises of HBRI on eight colonies. All the colonies selected were alike with respect to number of frames and bees present in them. The colonies were divided into two groups. On the first group the entrance trap was clipped while on the second group the newly devised bottom trap was fitted. The weight of pollen collected was compared and it was found to be significantly different from each other. The total yield of pollen from entrance trap and the fixed bottom trap in gm were found to be 12.55 + 1.66 (Mean ± SE) and 22.5 + 1.25 (Mean ± SE) respectively. The honey extracted from hives fitted with both types of traps was also compared and no difference was observed in their weight.

Keywords: *Pollen, Trap, Bees, Colonies.*

Introduction

Pollen, sometimes incorrectly called as flower sperm is a fine to coarse powder consisting of micro gametophyte or pollen grain which produces the male gamete of seed plant. It is bee's major source of protein, fatty substances, minerals and vitamins (Gary, 1975).

Bee pollen is the flower pollen collected by all honeybees for the purpose of feeding their larvae in the early stages of development. Collected flower pollen is accumulated as a pellet in pouches (pollen baskets) on the rear legs of the bees and it is the mixture of these pellets that comprises bee pollen (Campos *et al.*, 2005). The bees mix the pollen grains with a sticky substance that is secreted from their stomach, which allows the pollen to adhere to their legs in pollen baskets in order to safely transport to their hives. Bee pollen is one of the richest and purest natural foods ever discovered, and the incredible nutritional and medicinal value of pollen has been known for centuries.

The pollen collected by bees is superior to the pollen collected directly from plants as the bees are extremely discriminate about selecting the best pollen from the millions of grains that are present, bees only select those grains that are rich in all the nutrients, especially nitrogenous materials. Traps for collecting pollen pellets from legs of honey bees have been designed to trap pollen reserves. These traps vary greatly in size, appearance, and method of installation on the hive. Incoming pollen can be sampled for studies of foraging activities of bees and for identifying and classifying pollen sources. Stored pollen is a basic ingredient of pollen supplement for feeding bees. This pollen supplement provided by the beekeeper stimulates brood rearing when the natural pollen stored in comb is unavailable or inadequate in the

hive.

Pollen traps called pollen guards were first used by Farrar (1934) to prevent bees from bringing pollen into the hive. Todd and Bishop (1940) improved these guards by changing the grid from perforated metal to 5-mesh hardware cloth. For pollen identification studies Nye (1959), constructed a trap that fits underneath the hive and had an opening on the side for removing the tray filled with pollen. A trap that was inserted in the front entrance for obtaining small samples of pollen in short time was developed by Stewart and Shimanuki (1971).

Pollen traps vary greatly in design and positioning on the hive, but the basic principle is same i.e. a grid to remove the pollen from the bees and a tray to collect them.

Moisture in the pollen may be a serious problem in areas where humidity is high, so the traps should be weather proof and installed carefully to keep out moisture. Pollen should only be collected from disease free colonies and trapping should be done only during pollen flow of one quarter pound per day. During major nectar flows, pollen trapping is unprofitable as grids slow down bee activity which ultimately reduces honey production.

Freshly trapped pollen is perishable and it may be dried, frozen, or mixed with other materials and stored. For drying, the pollen should be spread on porous surface at a depth of one-half inch in an enclosed ventilated room and allow it to air dry. More rapid drying can be achieved in oven at 100 degrees F maximum. It can also be stored by putting it in paper bags in deep freezers below freezing temperatures.

Materials and Methods

The present work has been carried out in Honeybee Research Institute, National Agricultural Research Centre Islamabad, Pakistan during February-March 2009. We went under a series of steps before designing a new type of trap for collection of pollen from standard deep bottom hives. Initially, a double screen grid with a distance of 1.7mm was made (design no.1) but it did not proved to be effective as it disturbed the movement of bees from one screen to other and ultimately we did not collect any pollen. Then it was improved by removing one mesh from it (design no. 2). When this trap was checked the objections from the first designed pollen trap were removed but another serious problem arouse i.e. time consumption in the installation, as every time we have to remove the top covers of hive while inserting the pollen trap, which is not economical in terms of time spent by beekeeper on other management practices especially in spring season.

The design and location of the pollen trap on the hive may be changed to meet the prevailing needs and climatic conditions. Ease of installation, colony manipulation, minimum disturbance, cleanliness of pollen and size of tray should be given special attention while designing any trap. Thus keeping in view the above mentioned facts a further change was made in the trap (design no. 2) by making the grid which fits permanently in the hive and to collect pollen, just insert the single mesh (metal/plastic as both proved effective) which fits into that grid and when not needed can be removed easily.

The design of no. 2 trap was further modified by using double mesh screen and keeping the distance of 0.7mm between them. Finally, the structure of pollen trap was made strong by using fine wood of *Pinus walluchiana* and inserting it from the back side so that it will not cause any hindrance to the incoming bees. Thus, the bees enter the hive through an opening at the front of hive and while passing through the mesh grid, most of the pollen pellets dislodged from the hind legs of the returning bees, fall into a tray covered by screen that allows the pollen pellets but not the bees to pass. The size of holes is also a crucial factor as it must not damage bees or restrict their normal flight activity. It is hoped that this new design of pollen trap produces reliable, consistent results and overcomes some of the problems encountered with other designs of traps.

Pollen Collection

After designing the new trap a trial was laid

down on 11/02/2009 in the premises of HBRI on eight colonies. All the colonies selected were alike with respect to number of frames and bees present in them. The colonies were divided into two groups. One group of four colonies had the entrance trap fitted at the entrance and on other four the newly devised bottom trap was fixed.

Each trap was fixed on the hives at 10am and removed at 2pm. The experiment was continued for three weeks and data was taken twice a week. The pollen collected each day was stored in plastic bottles and weighed.

A total of 40 samples of pollen were collected from the hives by using pollen trap in front of the hive for 4hrs interval throughout the experiment. These pollen samples were removed from the hind legs of honeybees on a rack fitted in a tray inside the trap, as bees pass through the trap, the loads on their legs fell down. After 4hrs interval traps were removed and pollen loads were collected, weighed and spread on the clean white paper for sorting. The pollen of different colour was stored in small glass bottles.

A field survey was conducted and bees with pollen loads on their legs were collected from different plants. The pollen loads were then pushed off the hind legs into individual specimen of polythene bag. The bees were released unharmed or sometimes killed by using the killer bottle. These colours were matched with those pollen pellet trapped by pollen traps, which helped in identifying the source of pollen.

Results and Discussion

To analyze our data we used SPSS statistical programme version fourteen in which the approach is rather different as the statistics are not displayed on the spread sheet but in separate windows. Comparisons between means were made using the least significant difference (LSD) at 0.05 probabilities (SPSS). For statistical data, standard descriptive statistics were performed for each of the quantitative parameters.

The dependence of honeybees on pollen in several ways is well documented (Stanley and Linskens, 1974, Wille *et al.*, 1985). Pollen is used primarily as a source of essential aminoacids required by honeybees (De Groot, 1953) in protein synthesis. In our study we worked on the newly devised pollen trap fitted on *Apis mellifera* colonies. The brood rearing capacity of *Apis mellifera* is known to be improved by the addition of pollen ash to a chemically defined diet (Herbert and Shimanuki, 1978). The nutritional status and biochemical composition of the royal jelly as influenced to a large extent by the type of pollen nutrition (Stanley and Linskens, 1974), may affect the composition of food fed to honeybee larvae.

The use of pollen trap in pollen studies is not a new phenomenon. Wille *et al.*, (1985) reported that the weight of pollen collected by a colony, calculated from amounts collected in pollen traps, varies from 10 to 25kg/year. The mean weight of pollen collected from the entrance clipped pollen trap ranged from 0.5 to 49.0 gm and for the newly devised fixed bottom trap the range was 6 to 45gm respectively. The Lavene's Test for equality of variance showed the P value greater than 0.05 so the weight of pollen collected was compared by using non parametric Mann-Whitney U Test and it was found that they were significantly different from each other (Mann-Whitney U = 512.5, $P < 0.00$). The total mean yield of pollen (gm) from entrance trap and the fixed bottom trap were found to be 12.55 ± 1.66 (Mean $\pm$ SE) and 22.5 ± 1.25 (Mean $\pm$ SE) respectively (Fig. 1).

The pollen brought in by the bees at Rothamsted during 1945 and 1946 has been collected daily by using a newly designed pollen trap and it was found that legumes, rosaceae trees/ shrubs and forest trees share 54, 15 and 11 % of the total collected pollen (Synge, 1947). Cundill (1986) tested a simple trap at three locations in Scotland and collected data at monthly intervals for three years which showed a clear link between pollen and the dominant plant species of the area. In our study after matching the colour of pollen colleted from trapped bees while foraging plants with that of pollen collected in pollen traps also showed a positive relationship between the pollen and prominent botanical sources of the area around the experimental trial. The results obtained also show some important pollen colours as follows;

Plant	Pollen load colour
Sillibum sp.	Sea green
Lallemantia royleana	Green
Brassica compestris	Bright yellow
Calendula arvensis	Orange
Callestemon citrinus	Yellowish green
Citrus sativa	Light orange
Corrinadrum sativum	Grayish white
Grewia asiatica	Off white
Justica adhatoda	Off white
Prunus persica	Light orange
Rosa indica	Yellow
Trifolium alexandrianum	Brown
Eucalyptus cammoldulensis	Yellowish green
Taraxacum officinale	Bright yellow
Linum usitatissimum	Dirty green
Prunus armeniaca	Greenish white
Raphanus sativus	Yellow
Euphorbia sp.	Reddish yellow

The colour of pollen can help in identifying the plants present in the area (Kirk, 1994). This method is usually accurate and can often identify the pollen to genus and species level but it is time consuming and requires expertise.

In order to evaluate the use of three different types of traps referred as entrance, bottom and board, an investigation carried out in Poland (Bobrzecki and Wilde, 1987) showed that total pollen collected in 1986 was 2.47, 0.69 and 0.70 kg respectively for bottom, entrance and board traps. In 1987 the corresponding figures were 1.58, 0.50 and 0.41kg. They also found that amount of pollen did not lower the amount of honey produced which is in agreement with our results as we also did not find any difference in the amount of honey harvested from hives fitted with different traps (One Way ANOVA, $F_{(1, 7)} = 16.59$, $P > 0.001$). The mean weights of honey (kgs) produced from colonies fitted with front and fixed bottom trap were 10.43 ± 2.51 (Mean $\pm$ SE) and 8.51 ± 1.39 (Mean $\pm$ SE) respectively (Fig. 2).

Pollen traps have been used extensively by the various beekeepers during the summer months to collect surplus pollen brought in by the bees which can be used in the following spring to stimulate brood rearing at a time when pollen is in short supply.

Stephen and Robert (2001) indicated that honeybees respond to deficiencies in the quantity or quality of their pollen reserves by increasing the gross amount of pollen returned to the colony, rather than by specializing in collecting pollen with greater pollen content.

They also suggested that colonies may respond to changes in their pollen stores by adjusting the numbers of inexperienced to experienced foragers within their foraging populations.

The newly designed trap used in our study does not fit at the existing entrance but is placed at the bottom of the hive which allows the bees to have easy free access without getting crowded or aggressive. This ensures that they can replenish or collect their own pollen stores in good quantity. This trap is designed for beekeepers to allow them to keep the trap on the hive throughout the summer and collect the pollen on alternate weeks or after every 2-3 days of week without disturbing bees and avoiding labour of putting and removing traps every time. The surplus pollen should be collected every other day and stored properly as a byproduct for feeding colonies when required.

However, this requires more critical evaluation by future experiments involving collection of pollen over several months from single and mixed plant populations.

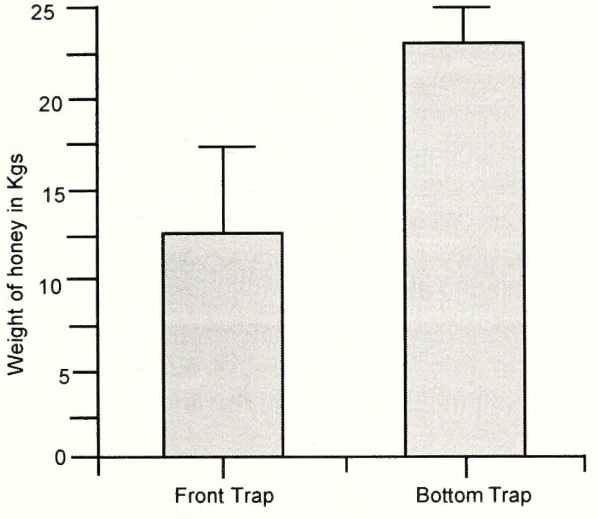

Fig. 1: The weight of pollen collected from the entrance fitted pollen trap (T1) and newly devised fixed bottom trap (T2).

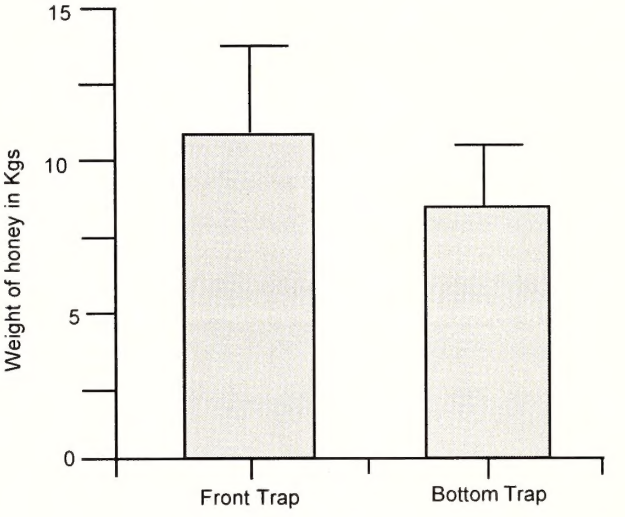

Fig. 2: The weight of honey harvested from hives fitted with front and newly devised fixed bottom pollen trap.

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Biodiversity of the short horned grasshoppers of the tribe Oedipodini (Orthoptera: Acrididae: Acridinae) in Kashmir Himalayas

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Abstract

Tribe Oedipodini is redefined. Key to genera of Oedipodini found in Kashmir and diagnostic characters of each genus are given. Key to species wherever necessary along with their habitats are also given.

Keywords: *Biodiversity, Oedipodini, Kashmir.*

Tribe Oedipodini Scudder, 1875

The tribe Oedipodini can be characterized as follows:-

Body somewhat sturdy; antennae always filiform; fastigial foveolae present or absent, if present they are never contiguous in front, often they are small or triangular, more rarely oblong trapezoidal, but not quadrangular; frons vertical; pronotum usually without lateral carinae, if present, they are weak and less developed, median carina in some species high; tegmina and wings well developed, tegmina with spurious median vein strong, in some species absent or weak; wings often brightly marked with different shades of blue, dark blue, red or yellow, quite often with a black band; arolium small.

Key to genera of the tribe Oedipodini Scudder found in Kashmir

1. Dorsum of pronotum without x-shaped pattern.....2
----Dorsum of pronotum with x-shaped pattern.....*Oedaleus* Fieber

2. Median carina of pronotum intersected by two transverse sulci.....3
---Median carina of pronotum entire or intersected by only one transverse sulcus 5

3. Body small to medium size; median carina of pronotum not forming teeth like projection 4
---Body small; median carina of pronotum forming teeth like projections..... *Trilophidia* Stal

4. Frontal ridge flat or with a depression near median ocellus; pronotum longer than its width, with angular posterior margin..... 9
----Frontal ridge with a groove throughout its length; pronotum as long as or shorter than its width, with widely rounded posterior margin.....*Acrotylus* Fieber

5. Pronotum with well developed median carina.....6
----Pronotum with weak median carina.....
.....*Aiolopus* Fieber

6. Median carina of pronotum not excised at posterior sulcus..... 7

----Median carina of pronotum slightly excised at posterior sulcus.....8

7. Antennae longer than head and pronotum together; frontal ridge shallowly sulcate; pronotum not crest like, angulated behind with the tip rounded off.....*Dittopternis* Saussure
----Antennae shorter than head and pronotum together; frontal ridge flat; pronotum crest like, acutely angulated behind.....
.....*Gastrimargus* Saussure

8. Antennae about as long as head and pronotum together; frontal ridge flat; median carina of pronotum equally raised in prozona and metazoan, slightly excised by posterior transverse sulcus; wings without a dark transverse band; thorax ventrally with dense hairs.....
.....*Locusta* Linnaeus
----Antennae slightly longer than head and pronotum together; frontal ridge sulcate; median carina of pronotum strongly raised in prozona and moderately in metazoan, deeply excised by only one transverse sulcus; wings with a dark transverse band or the band may be weak or absent; thorax ventrally without dense hairs.....*Oedipoda* Latreille

9. Tegmina with spurious median vein strongly approaching M apically; wings usually with a dark band..... *Sphingonotus* Fieber
----Tegmina with spurious vein at equidistant from M and CuA; wings without a dark band .....*Leptopternis* Saussure

10. Pronotum with small sparse tubercles, lower margin of hind femur with long dense hairs .....*Pternoscirta* Saussure
-----Pronotum without small sparse tubercles, lower margin of hind femur without long dense hairs..... *Epacromius* Uvarov

Genus *Oedipoda* Latreille

Oedipoda Latreille, 1829. *In Cuvier, R. Anim. Ed.,* 2, 5:188.
Type-species: *Gryllus caerulescens* Linnaeus (= *Gryllus caerulescens caerulescens*)
Ctypohippus Fieber, 1852. *Kelch. Orth. Oberschl.*,pp 2.

Distribution: Asia, Europe, N. Africa.

Diagnosis: Small to medium sized insects; antennae filiform, slightly longer than head pronotum together; fastigium of vertex concave, with raised lateral carinulae; fastigial foveolae present; frontal ridge sulcate; pronotum with median carina sharp, distinctly raised, sharply intersected by posterior transverse sulcus; lateral carinae often present, strongly interrupted by transverse sulci and obliterated in metazoan, dorsum rugose and tuberculate, metazoan longer than prozona, its posterior margin angular; mesosternal interspace longer than wide; tegmina and wings fully developed, wings with dark band, base of wing brightly coloured; arolium small; male with supra-anal plate elongate, angular, cercus conical, subgenital plate conical with obtuse apex, epiphallus with narrow bridge and bilobate lophi; female with ovipositor valves short, tips recurved, ventral valve with external lateral projection.

The genus can easily be distinguished in having pronotum with median carina deeply excised at posterior transverse sulcus and dark band of the wing usually sends off a branch towards the base of the wing.The genus is represented by two species in Kashmir.

Key to species of *Oedipoda* Latr. Found in Kashmir

1. Tegmina with apical half hyaline; wings with dark band narrow reaching upto the posterior wing margin.....*Oedipoda himalayana* Uvarov
----Tegmina with only apex hyaline; wings with dark band wide, reaching upto the mid of posterior wing margin ..... *Oedipoda miniata miniata* (Pallas)

***Oedipoda himalayana* Uvarov**

Oedipoda himalayana Uvarov, 1925. *Mission Babaull Inde, Acrididae,* 22. *Oedipoda himalayana* Uvarov; Bei-Bienko And Mischenko, 1951. *Acad. Nauk.SSR*,235.

Distribution:Kashmir,Afghanistan, Uzbekistan.

This species has been recorded from Kashmir by Bei-Bienko and Mischenko (1951), but the present authors could not collect any specimen of this species.

Material examined: IARI,New Delhi collection, India: Kashmir, Rising Gorg,6000ft, 2F, 04.x.1923 (Fletcher).

***Oedipoda miniata miniata* (Pallas) (Fig. 1)**

Gryllus miniatus Pallas, 1771. Reise. Russ. Reiches., 1: 467.

Oedipoda miniatus (Pallas), Chopard. 1922. *Fauna de France*. 3: 134,163.

Distribution: Southern Europe, Kazakistan, West Siberia, Asia, North Africa. The general morphological characters are same as described under genus. The genitalic characters are as follows:-

Males having supra-anal plate with wavy apical margins, tip nearly rounded, cercus elongate, broader at base, narrow apically; epiphallus with bridge narrow, undivided medially, ancorae broad in the middle with pointed tips, lophi bilobate; female with supra-anal plate broad, subtriangular, slightly truncated on sides near apex, covered with setae; subgenital plate with posterior margin wavy, setae present , egg guide short about one and a half times longer than wide; ovipositor valves shorter than lateral apodeme, with blunt tips; spermatheca with apical diverticulum short, pre-apical diverticulum long, much broad, sac like with a tubercle like projection facing towards the tip of apical diverticulum.

Material examined: 5 F, 2 M, Kashmir: Kupwara, Karnah, Gundi Gujran on grass, 9.ix. 2005 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from stony soil with sparse grassy vegetation.

Remarks: This subspecies has been recorded for the first time from Kashmir.

Genus *Sphingonotus* Fieber

Sphingonotus Fieber, 1852. *Kelch.Orth. Overschles*, 2; Fieber, 1853. *Lotos*, 3: 124.

Type-species: *Gryllus locusta caerulans* Linne.

Distribution: Cosmopolitan

Diagnosis: Medium sized insects; antennae filiform, slightly longer than or about as long as head and pronotum together; fastigium of vertex concave, with lateral and sometimes with median carinulae; fastigial foveolae present, sometimes indistinct; frontal ridge shallowly sulcate; pronotum saddle shaped, narrowed and constricted in prozona, median carina low, thin sometimes indistinct and intersected by three transverse sulci, lateral carinae absent, metazoan longer than prozona, its posterior margin obtusely angular, with almost rounded apex; mesosternal interspace longer than wide; tegmina and wings fully developed, spurious median vein of tegmina more convex than the adjacent sector R and M and apically comes closer to M than CuA, wings with coloured base, often with a dark Band of varied length; spurs of hind tibia not specialized; arolium small; male epiphallus with moderately narrow bridge, large ancorae and with bilobate lophi.

The genus can easily be identified on the basis of median carina of pronotum never raised in prozona; female with subgenital plate having acute posterior margin; ovipositor short, with moderately robust valves, ventral valve with externo-lateral projections. In Kashmir the specimens of this species are found in stony soil and wings are usually with a dark band. The genus is represented by four species in Kashmir.

Key to species of *Sphingonotus* found in Kashmir

1. Mesosternal interspace narrow, less than twice as wide as long; wings with dark transverse band well developed and broad 2

--------Mesosternal interspace wide, twice or more as wide as long; wings with dark band diffused.....*Sphingonotus kashmirensis* Uvarov

2. Wings sky blue near the base 3
---------Wings colourless near the base.....
.....*Sphingonotus savignyi* Saussure

3. Smaller species; wings with dark transverse band distinctly wide, hardly attenuating towards posterior end.....
..*Sphingonotus balteatus himalayanus* Uvarov
--------Larger species; wings with dark transverse band never wide, conspicuously attenuating beyond middle and towards its posterior end.....*S. longipennis* Saussure

***Sphingonotus kashmirensis* Uvarov**
Sphingonotus kashmirensis Uvarov, 1925. *Mission Babault Inde, Acrididae,* 18pp.

Distribution: Kashmir, Eastern Afghanistan.

The species has been described and recorded by Uvarov (1925) and Bie-Bienko and Mischenko (1951) from Kashmir. However the present authors could not collect any specimen of this species from the region.

***Sphingonotus savignyi* Saussure (Fig. 2)**
Sphingonotus savignyi Saussure, 1884.*Mem. Soc. Geneve*,xxviii (9):198,208.

Distribution: India, Pakistan, North Africa, Arabia, Palestine.

The characteristic features of this species same as described under genus and in the key to species.

Material examined: 5 F, 4 M, Kashmir: Kupwara, Karnah, Gundi Gujran on grass, 9.ix.2006 (Shabir A. Reshi); 1 F, 2 M, Baramulla, Gurez, Dawar on grass,16.ix.2006 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from stony soil having patches of grassy vegetation.

Remarks: This species has earlier been recorded from Kashmir by Bie-Bienko and Mischenko (1951).

***Sphingonotus balteatus himalayanus* Uvarov**
Oedipoda balteata Serville, 1839. *Ins. Orth.*734.
Oedipoda latifasciata Walker, 1870. *Zoologist,* 28: 2299.
Sphingonotus amaranthinus Saussure, 1884.*Mem. Soc.Phys.Hist.Nat. Geneve*, 28(9): 205.
Sphingonotus bifasciatus Innes Bey, 1919. *Bull.Soc.Ent.Egypte*, 11: 45,48.
Sphingonotus balteatus himalayanus Uvarov,1923.*J.Bombay Nat. Hist. Soc.* 29: 646.

Distribution: India (Kashmir), Pakistan, Arabia, Egypt.

The species has already been described by Bei-Bienko and Mischenko (1951).

Remarks: This species has earlier been recorded by Kirby (1914) from Kashmir. The present authors however could not collect any specimen of this species from the region.

***Sphingonotus longipennis* Saussure (Fig. 3)**
Sphingonotus longipennis Saussure,1884. *Mem.Soc.Phys.Hist.nat. Geneve,*28(9):197-203
Sphingonotus Indus Saussure, 1884. *Ibid.*204.

Distribution: India, Pakistan, Africa, Europe.

The charateristic features of the species are same as described under genus and in the key to the species except in the followings:-

Male with supra-anal plate subtriangular, lateral margins curved medially, cercus elongate, more than twice as long as wide, with rounded apex; subgenital plate wide, flattened, wider than long, apex obtusely rounded, epiphallus with bridge narrow and undivided medially, ancorae broad in the middle, lophi bilobate; female with supra-anal plate subtriangular, covered with setae apically, subgenital plate with wavy posterior margin, setae absent, Jannone's organ present, ovipositor with dorsal valve much shorter than lateral apodemes, spermatheca with apical diverticulum short, tubular and narrow, pre-apical diverticulum long and sac like.

Material examined: 15 F, 8 M, Kashmir: Kupwara,

Handwara, Shatgund Payeen on grass, 6.ix.2005 (Shabir A. Reshi); 4 F, 9 M, Kupwara, Handwara, Shatgund Payeen on grass, 11.ix.2006 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from the stony soil having sparse vegetation along the river bank.

Remarks: This species has earlier been recorded from Kashmir by Bie-Bienko and Mischenko (1951). But the material collected by the authors slightly differs from the description given by Bie-Bienko and Mischenko in having hind tibia without dark band, instead it is having white band. It also differs from the description given by Kirby (1914) in having median carina present on pronotum.

Genus *Oedaleus* Fieber

Oedaleus Fieber, 1853. *Lotos.,* 3: 126 (as subgenus of *Oedipoda* Serville). *Oedaleus* Stal, 1873. *Recens. Orth.,* 1:123 (as subgenus of *Pachytylus* Fieber). Type-species: *Acrydium nigrofasciatum* Degeer.

Distribution: Africa, Arabia, S. Europe, Middle East, erstwhile USSR, China, Oriental region, Australia.

Diagnosis: Medium sized insects; antennae filiform, longer than head and pronotum together; fastigium of vertex flat or slightly concave with obtuse lateral carinulae, with or without median longitudinal carinula; frontal ridge flat or shallowly sulcate with marginal carinulae diverging ventrally, reaching or nearly reaching upto clypeus; pronotum with obtuse median carina, often intersected by posterior transverse sulcus, lateral carinae absent, dorsum with x-shaped pattern, metazoan equal to or little longer than prozona, posterior margin rounded or angular; mesosternal interspace wider than long, widening posteriorly; tegmina and wings fully developed, spurious median vein approximately equidistant between M and CuA, sometimes closer to CuA than M at base, wings usually with a dark band; hind femur with external ventral knee lobe acutely rounded; arolium of medium size or small; male with supra-anal plate angular, cercus conical with obtuse apex, subgenital plate conical with obtuse apex; females with ovipositor valves robust, curved, ventral valve with elongate external lateral projection, spermatheca with sac like apical diverticulum with or without a short pre apical diverticulum.

The genus can easily be distinguished from other genera on the basis of having a light x-shaped marking on the dorsum of pronotum.

The genus is represented by three species in Kashmir.

Key to species of the genus *Oedaleus* Fieber found in Kashmir

1. Dark band of the hind wing reaches anteriorly to the anterior margin; spermatheca with small apical diverticulum 2
----Dark band of the hind wing not reaching to the anterior margin; spermatheca without apical diverticulum..... *Oedaleus abruptus* (Thunberg)

2. Pronotum with posterior transverse sulcus placed behind the middle; hind wing pale pink at base ..... *Oedaleus rosescens* Uvarov
----Pronotum with posterior transverse sulcus placed at the middle; hind wing pale yellow at base ..... *Oedaleus senegalensis* (Krauss)

***Oedaleus abruptus* (Thunberg) (Fig. 4)**

Gryllus abruptus Thunberg, 1815. *Mem. Acad. Sci. St. Petersb.*, 5:233.

Pachytylus (Oedaleus) abruptus Stal, 1873. Recens. Orth., 1:127. *Oedaleus (Oedaleus) abruptus* Saussure, 1884. *Mem. Soc. Phys. Hist. Nat. Geneve*, 28(1): 117.

Oedaleus abruptus (Thunberg), Kirby, 1910. *Syn. Cat. Orth.* 3: 226.

Distribution: Afghanistan, India, China, Myanmar, Nepal, Srilanka, Thailand.

The distinguishing characters of this species are same as described under genus and in the key to species.

Material examined: 3 F, 1 M, Kashmir: Kupwara, Handwara, Shatgund Payeen on grass, 27.ix.2006 (Shabir A. Reshi); 4 F, 5 M, locality same as above, 03.x.2006 (Shabir A Reshi).

Habitat: The specimens of this species have been collected from the cultivated field having mixed vegetation of maize, sorghum and grasses along the river bank.

Remarks: This species has been recorded for the first time from Kashmir (India). Earlier, Perwin *et al.* (1985) recorded it from Muzaffarabad (POK).

***Oedaleus rosescens* Uvarov**
Oedaleus rosescens Uvarov, 1942. *Ann. Mag. Nat. Hist.,* 9(11): 589.

Distribution: India (Rajasthan, Punjab), N.E. Pakistan.

Material examined: 4 F, 3 M,Kashmir: Kupwara, Handwara, Shatgund Payeen on grass, 27.ix.2006 (Shabir A. Reshi).

Habitat: The specimens of this species have also been collected from the cultivated field having mixed vegetation of maize, sorghum and grasses along the river bank.

Remarks: This species has also been recorded for the first time from Kashmir.

***Oedaleus senegalensis* (Krauss) (Fig. 5)**
Pachytylus senegalensis Krauss, 1877. *Sber. Acad. Wiss. Wien.*,76(1): 56.
Ctypohippus arenivolans Butler, 1881. *Proc. Zool.Soc.Lond.*85.
Pachytylus mlokoziewizteki Bolivar, 1884.*Annl.Soc.Ent.Belg.,* 28:105.

Distribution: North Africa, erstwhile USSR, Middle East, Afghanistan, Pakistan, India.

Material examined: 4 F, 2 M, Kashmir: Kupwara, Handwara, Shatgund Payeen on grass,27.ix.2006 (Shabir A. Reshi).

Habitat: Same as in above mentioned two species.

Remarks: This species has also been recorded for the first time from Kashmir.

Genus *Trilophidia* Stal
Trilophidia Stal,1873. *Recens. Orth.*, 1:131.
Type-species: *Trilophidia cristella* Stal

Distribution: Ethiopian region,Oriental region and some parts of Palaearctic region

Diagnosis: Smaller sized insects; antennae short, slightly or distinctly widened apically, usually longer than head and pronotum together; fastigium of vertex concave with truncate apex and undulated lateral carinulae; fastigial foveolae irregularly triangular or oval, sometimes indistinct; frontal ridge sulcate; pronotum with median carina distinct in prozona with two teeth like projections due to deeply incised anterior sulci and it seems to be bidentate in profile, lateral carinae irregular, forming small teeth like lateral tubercles in front of first sulcus, strongly diverging or sometimes weak in metazoan, metazoan longer than prozona, slightly inflated, posterior margin rectangular with obtuse apex; mesosternal interspace wider than long; tegmina and wings fully developed, tegmina with spurious median vein come closer to M than CuA apically, hind wings without band, slightly coloured or colourless at base; female with spermatheca having short apical and large sac like pre-apical diverticula; ovipositor valves short, with robust curved valves, ventral valve with small rounded externo-lateral projection.

This genus can easily be distinguished from other genera on the basis of having two teeth like projections on prozona of pronotum.

The genus is represented by a single species in Kashmir.

***Trilophidia annulata* (Thunberg) (Fig. 6)**
Gryllus annulatus Thunberg,1815.
Mem.Acad.Sci.St.Petersb., 5: 234.
Oedipoda cristella Stal, 1860. Engenic's Resa. Orth.Stockholm, 3: 344.

Epacromia aspera Walker, 1870. *Cat.Derm.Salt. Br. Mus.,* 4: 775.

Distribution: India, Pakistan, Bangladesh, Srilanka, Myanmar, China, South East Asia.

Material examined: 1 F, 3 M, Kashmir: Baramulla,Uri,Uranbuha on maize, 13.ix.2005 (Shabir A. Reshi); 4 F, 5 M,Kupwara,Karnah, Gundi Gujran on grass, 24.ix.2005 (Shabir A. Reshi); 3 F, 3 M, Srinagar, Dachigam National Park on grass,12.x.2006 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from the fields having mixed vegetation of maize, sorghum and grasses and from the fields having short grasses and thorny vegetation.

Remarks: This species has earlier been recorded by Hollis (1965) from Kashmir, later Bhat & Qadri (1999) recorded it from Dachigam National Park.

Genus *Acrotylus* Fieber

Acrotylus Fieber,1853. *Lotos,* 3: 125.
Type-species: *Gryllus insubricus* Scopoli.

Distribution: Asia, Australia, Africa, South Europe.

Diagnosis: Small or medium sized insects; body covered with hairs; antennae filiform, longer than head and pronotum together; fastigium of vertex concave with margins raised; fastigial foveolae usually present , triangular in shape, sometimes indistinct; frontal ridge wide, sulcated, narrowing upwards, pronotum constricted just before middle, with well developed median and irregular tuberculate lateral carinae, which are sometimes absent in metazoan, median carina intersected by two transverse sulci, metazoan longer than prozona, its posterior margin broadly rounded; tegmina and wings fully developed; spurious median vein of tegmina close to CuA at base but at apex it is close to M; wings coloured at base with or without a dark band; hind tibia with inner pair of spur longer than outer pair.

The genus can easily be distinguished from other genera on the basis of having pronotum with indistinct median carina on prozona intersected by two transverse sulci, posterior margin broadly rounded.

The genus is represented by a single species in Kashmir.

***Acrotylus humbertianus* Saussure (Fig. 7)**

Acrotylus humbertianus Saussure,1884.*Mem. Soc.Phys.Hist.Nat.Geneve*, 28(9): 189.

Distribution: India,Pakistan,Srilanka, Afghanistan.

Material examined: 4 F, 6 M, Kashmir: Baramulla, Gurez, Dawar on grass,16.ix.2006 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from rocky soil having sparse vegetation.

Remarks: This species has earlier been recorded by Bei-Bienko and Mischenko(1951) from Kashmir.

Genus *Aiolopus* Fieber

Aiolopus Fieber, 1853.*Lotos.*,3:100.
Epacromia Fischer, 1853.*Orth.Eur.*, 296,360.
Aeolopus (Sic) Kirby, 1910. *Syn. Cat. Orth.*,3: 120
Aeoloptilus Bei-Bienko, 1966. *Zool. Zh.*,45: 1793.
Type-species: *Gryllus thalassinus* Fabricius

Distribution: India, Australia, Europe and Africa.

Diagnosis: Medium sized insects; antennae filiform as long as or longer than head and pronotum together; fastigium of vertex elongated, slightly concave with well developed lateral carinulae; fastigial foveolae present, elongate trapezoidal anteriorily reaching the fastigium of vertex; frontal ridge flat, more rarely with a groove; pronotum with median carina thin, low intersected by one transverse sulcus in front of the middle, lateral carinae absent, metazoan longer than prozona, its posterior margin obtuse angular, with rounded or obtuse apex; mesosternal interspace slightly wider than long; tegmina and wings fully developed; spurious median vein of tegmina sharp, strongly approaching M on the apex or nearly touching it; wings without dark band near the base colourless or slightly tinted; male with supra-anal plate elongate angular, cercus narrow conical with obtuse

apex; subgenital plate subconical with obtuse apex.

The genus can easily be separated from other genera on the basis of having pronotum with prozona constricted and without lateral carinae.

The genus is represented by single species in Kashmir.

***Aiolopus thalassinus* (Fabricius) (Fig. 8)**
Gryllus thalassinus Fabricius, 1781. *Species Insectorum*, 1:367.

Distribution: Ethopian region, North-West India, Palaearctic region.

Material examined: 4 F, 5 M, Kashmir: Kupwara, Handwara, Nowgam on grass, 28.viii.2004 (Shabir A. Reshi); 8 F, 6M, Srinagar, Dachigam National Park on grass, 11.ix.2004 (Shabir A. Reshi); 2 F, 7 M, Baramulla, Palhalan on maize, 28.x.2005 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from the grassy fields.

Remarks: This species has been recorded from Kashmir for the first time.

Genus *Dittopternis* Saussure
Dittopternis Saussure, 1884. *Mem.Soc. Phys.Nat. Hist. Geneve,* 28(9): 52,125.
Type-species: *Dittopternis ceylonica* Saussure

Distribution: India, Srilanka, Australia, South Africa.

Diagnosis: Medium sized insects; head broad; antennae longer than head and pronotum together; fastigium of vertex concave, longer than broad; frontal ridge sulcated; pronotum with median carina intersected by the principal sulcus before the middle, front border truncated, hind border rectangular with tips rounded; tegmina and wings fully developed, tegmina long, narrow densely reticulated, opaque beyond the middle, wings with base coloured followed by a curved black band, wings reaching beyond the abdomen; hind tibia with external apical spine absent, spines yellow with tips black, inner pair of spurs at the apex comparatively longer than the outer pair, upper carina of hind femur with spinules; male epiphallus with bridge broad , ancorae with tips pointed, lophi bilobate; female with ovipositor valves having blunt tips.

The genus is represented by a single species from Kashmir.

***Dittopternis venusta* (Walker) (Fig. 9)**
Oedipoda venusta Walker, 1870. *Cat. Derm.Salt.Br.Mus.,* 4: 740.

Distribution: India.

Material examined: 5 F, 5 M, Kashmir: Baramulla,Uri,Chandanwari on maize, 8.ix.2004, (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from Maize fields adjacent to forest.

Remarks: This species has been recorded for the first time from Kashmir. Earlier Sharma and Gupta (1977) have recorded it from Jammu region of J & K state.

Genus *Gastrimargus* Saussure
Gastrimargus Saussure, 1884.
Mem.Soc.Phys. Nat. Hist. Geneve, 28(9): 109,110.
Type-species: *Gryllus verescens* Thunberg

Distribution: Asia, Australia, Africa.

Diagnosis: Medium to large sized insects; antennae filiform, about as long as or shorter than head and pronotum together; fastigium of vertex with truncate apex and well developed lateral and weakly developed

median carinulae; fastigial foveolae if visible elongate and triangular; frontal ridge flat, wide with obtuse lateral carinulae; pronotum longer with sharply raised median carina which is sometimes entire and sometimes cut by only weak posterior sulcus, lateral carinae absent, x-shaped marking absent, rarely present, metazoan longer than prozona, its posterior margin acutely angular; mesosternal interspace wider than long; tegmina and wings fully developed, reaching beyond the apex of abdomen; spurious median vein closer to M than CuA throughout its length, dark band of the wings variable, basal area of the wing pale blue, pale greenish, yellow, pale yellow or bright sulphur yellow.

The genus can easily be separated from other genera on the basis of having pronotum with median carina raised, crest like, entire or intersected by one transverse sulcus, posterior margin acutely angular.

The genus is represented by two species in Kashmir.

Key to species of *Gastrimargus* Saussure found in Kashmir

1. Median carina of pronotum distinctly intersected by posterior transverse sulcus; inner margins of hind femur blue black in colour.....*G. africanus* Saussure
----Median carina of pronotum not distinctly intersected by posterior transverse sulcus; inner margins of hind femur dirty yellow in colour.....*G. marmoratus* Thunberb

Gastrimargus africanus Saussure (Fig. 10)

Oedaleus (Gastrimargus) marmoratus var. *africana* Saussure, 1888.*Mem.Soc.Phys.Nat. Hist. Geneve,* 30(1): 39.

Distribution: India: Kashmir, H.P.,Bihar,Goa, Pakistan, Africa, South of Sahara, S.W.Africa.

Diagnosis: The characteristic features of the species are same as described under genus and in the key to species.Some additional characters are as follows:

Hind tibia reddish apically, the inner pair of spurs longer than outer pair; male epiphallus with large bridge, lophi bilobate; female with supra-anal plate subtriangular, sugenital plate with posterior margin wavy, egg guide long, dorsal ovipositor valve with incurved blunt tip, as long as lateral apodeme, ventral valve with concave depression.

Material examined: 6F,3M, Kashmir: Kupwara, Handwara,, Nowgam on grass, 28.viii.2004 (Shabir A. Reshi); 6F, 3 M, Baramulla, Uri, Chandanwari on grass, 13.ix.2005 (Shabir A. Reshi); 2F,11M, Srinagar, Dachigam National Park on grass, 22. ix.2005 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from the grassy range land surrounded by forest and from fields having mixed vegetation of grasses and bushes.

Remarks: This species has earlier been recorded from Kashmir by Bhat & Qadri (1999). Mahmood and Yousuf (1999) also recorded it from POK.

Gastrimargus marmoratus (Thunberg)

Gryllus marmoratus Thunberg, 1815. *Mem. Acad. Sci. St. Petersb.,*5: 232.

Distribution: India: Kashmir, Assam; Japan.

The collected specimens fully agree with the description given by Bei-Bienko and Mischenko (1951) and Ritchie (1982).

Material examined: 3 F, 4 M, Kashmir: Baramulla, Uri, Chandanwari on grass,01.ix. 2007 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from range land surrounded by forest.

Remarks: This species has earlier been

recorded from Kashmir by Bei-Bienko and Mischenko (1951).

Genus *Locusta* Linnaeus

Locusta Linnaeus, 1758. *Syst. Nat.*,1: 431.
Oedipus Berthold, 1827.*Weimar, Indistr. Compt.*,402.
Pachytylus Fieber, 1853.Lotos, 3: 121.
Type-species: *Gryllus (Locusta) migratorius* Linne.

Distribution: All over the world.

Diagnosis: Large sized insects; antennae filiform, about as long as head and pronotum together; fastigium of vertex slightly concave, not delimited anteriorly from the frontal ridge and extending roundly over into it; frontal ridge wide, flat, slightly constricted and depressed at the median ocellus; median carina of pronotum slightly concave or arcuate, intersected by posterior transverse sulcus, metazoan slightly longer than prozona, its posterior margin almost rounded or obtusely angular; mesosternal interspace about as long as wide or slightly longer; thorax ventrally with dense hairs making tomentum; tegmina and wings fully developed; spurious median vein of tegmina closer to CuA than to M, wings without dark band; male with supra-anal plate angular, cercus with obtuse apex, subgenital plate conical with subacute apex; female ovipositor short, robust with curved valves, ventral valve with angular, external, lateral projections. The genus can easily be separated from other genera on the basis of having thorax on the ventral side covered with dense hairs; wings without dark band; body robust.

The genus is represented by a single species in Kashmir.

***Locusta migratoria* Linnaeus (Fig. 11)**

Gryllus (Locusta) migratoria Linnaeus,1758. Syst.Nat. 1(10): 432.

Distribution: India, Pakistan, Kazakistan, Africa, Southwestern Pacific.

Material examined: 3 F, 2 M, Kashmir: Baramulla,Gurez, Dawar on maize,18.ix.2004 (Shabir A. Reshi).

Habitat: The specimens of this species have been collected from maize fields along the river bank (Kishan Ganga) at an altitude of 8000ft.

Remarks: This species has been recorded for the first time from Kashmir (India). Earlier, Mahmood and Yousuf (1999) recorded it from POK.

Genus *Leptopternis* Saussure

Shingonotus (Leptopternis) Saussure, 1884. *Memoires de la Societe de Physique et D'Histoire Naturelle de Geneve,* 28(9): 193.
Type-species: Oedipoda gracilis Eversmann

Distribution: From Northwestern Mongolia and Dzungaria to Sahara.

Diagnosis: Medium sized insects; antennae filiform, longer than head and pronotum together; fastigium of vertex concave, lateral carinulae present; fastigial foveolae present, triangular; frontal ridge shallowly concave; pronotum with linear median carina, lateral carinae absent, dorsum crossed by three sulci, metazoan longer than prozona, its posterior margin obtusely angular; mesosternal interspace wider than long; tegmina and wings fully developed, wings without dark band; male with supra-anal plate elongate and angular, cercus narrow, conical with obtuse apex, epiphallus with a narrow bridge, ancorae large, lophi bilobate; females with acutely produced ovipositor valves.

The genus is represented by a single species in Kashmir.

***Leptopternis gracilis* (Evermann)**

Oedipoda gracilis Evermann, 1848. *Addit. Fisch.Waldh. Orth.Ross.*,10.

The species has been recorded from Kashmir by Bei-Bienko and Mischenko (1951). Later, Mahmood and Yousuf (1999) recorded it from POK. However, the present authors could not collect any specimen of this species.

Genus *Pternoscirta* Saussure

Pternoscirta Saussure, 1884. *Mem.Soc. Geneve,* 28(9): 52,127.
Type-species: *Pternoscirta cinctifemur* (Walker)

Distribution: Oriental region.

Diagnosis: Medium sized insects; ventral part of body and legs with long dense hairs; head short, somewhat rugose; vertex short, wide, flat; fastigial foveolae not reaching to the anterior margin of fastigium; pronotum slightly roughened with small sparse tubercles, median carina distinct, moderately raised; opening of tympanal organ widely uncovered; spurious median vein of tegmina comes closer to M than CuA apically, wings coloured basally, dusky on the apex and along the anterior margin, dark band absent; hind tibia with inner pair of spurs longer than the outer pair; arolium nearly equal to half the length of claw.

The genus is represented by a single species in Kashmir.

***Pternoscirta caliginosa* (DeHaan)**

Acridium (Oedipoda) caliginosum De Haan, 1842. *Temm. Verh. Orth.* 161.

Distribution: India (Kashmir, Sikkim), South China, Malacca.

Remarks: The species has been recorded from Kashmir by Bei-Bienko and Mischenko (1951). However, the present authors could not collect any specimen of this species.

Genus *Epacromius* Uvarov

Epacromius Uvarov, 1942. (1941). *Trans. Amer. Ent. Soc.*, 67: 337,338.
Type-species: *Epacromius tergestinus* Charpentier

Distribution: Palaearctic & Oriental regions.

Diagnosis: Medium sized insects; body slender; fastigium of vertex with apex rounded; fastigial foveolae well developed, elongated; frontal ridge flat or shallowly sulcate at least in males; pronotum with median carina thin, low, lateral carinae absent; mesosternal interspace open; tegmina and wings fully developed, spurious median vein of tegmina often irregular, extending along the middle field or runs moderately close to M apically; male subgenital plate flattened.

The genus is represented by a single species in Kashmir.

***Epacromius coerulipes* (Ivano)**

Epacromius coerulipes Ivano, 1887. *Trudy obshchestva Ispytatelei prirody Khar' Kovskogo Universiteta,* XXI: 348.

Distribution: Europe, Kazakistan, Australia, Hungary, Mongolia, Korea, China.

Remarks: The species has been reported from Kashmir by Bei-Bienko and Mischenko (1951). However, the present authors could not collect any specimen of the species.

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The authors are greatly indebted to Prof. R. C. Bhagat, Head, P.G. Department of Zoology, University of Kashmir, Srinagar. Thanks are also due to Chief Wildlife Warden, Kashmir, for granting permission to visit Dachigam National Park. We are also thankful to the government authorities for their help and co-operation in carrying out the survey in far flung and disturbed areas of the state.

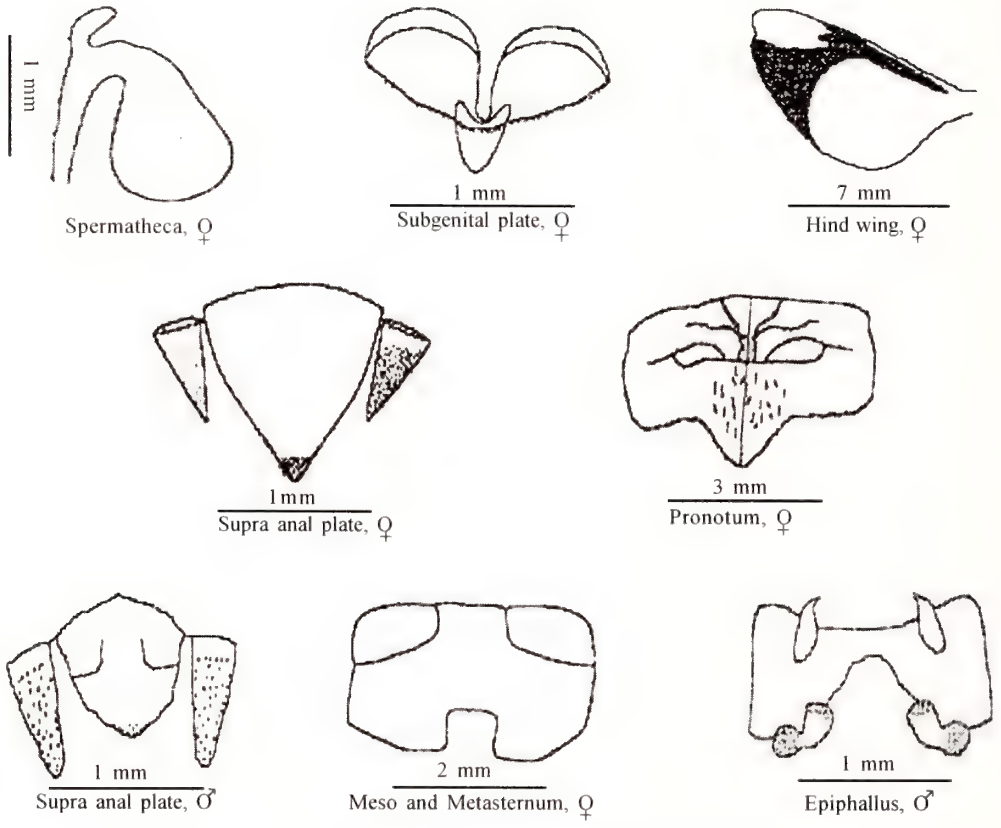

Fig. 1: *Oedipoda miniata miniata* (Pallas)

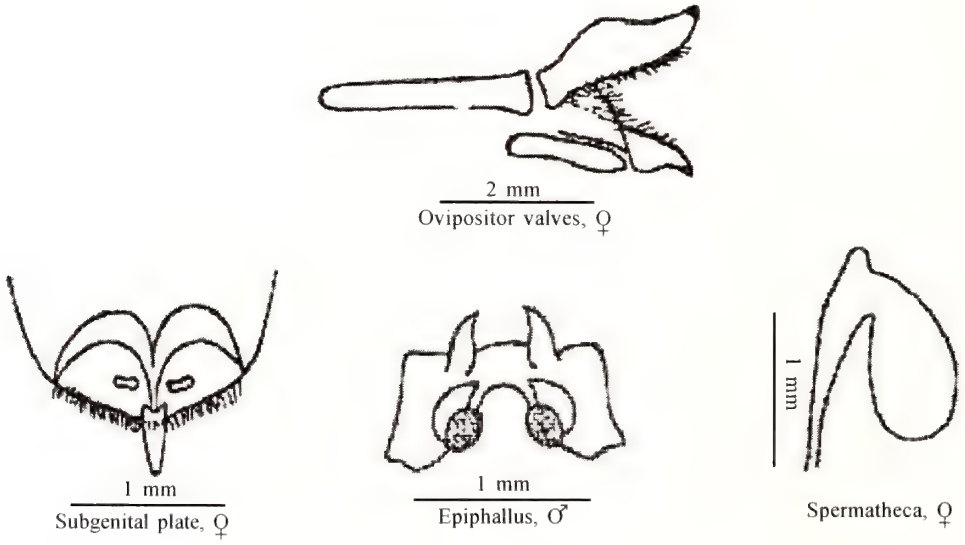

Fig. 2: *Sphingonotus savignyi* Saussure

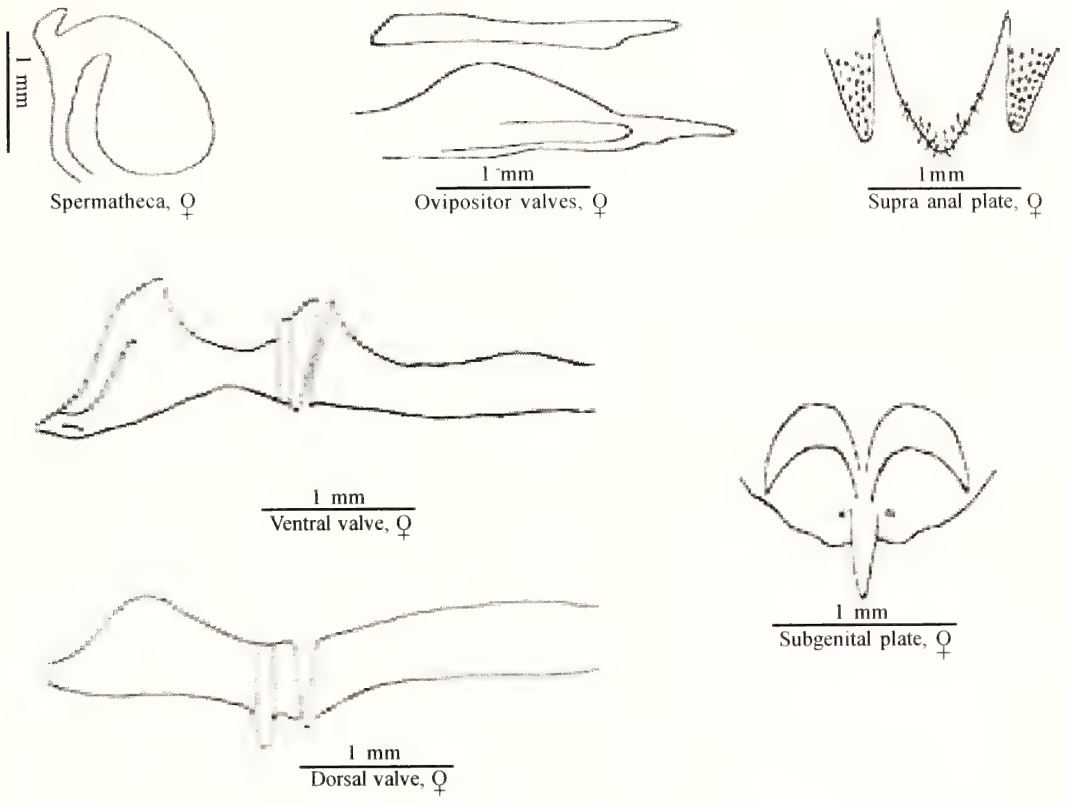

Fig. 3: *Sphingonotus longipennis* Saussure

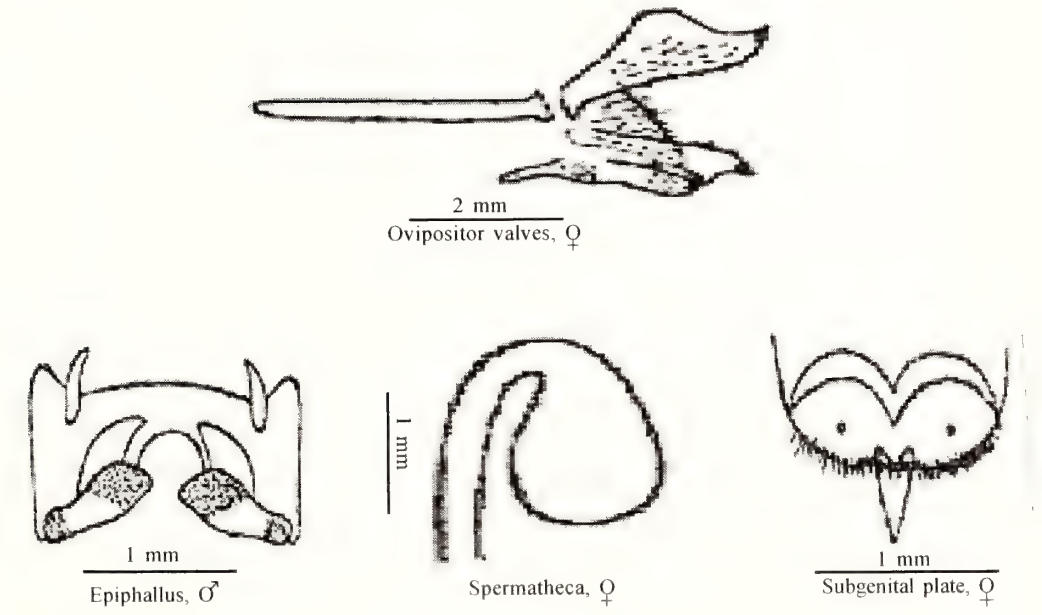

Fig. 4: *Oedaleus abruptus* (Thunberg)

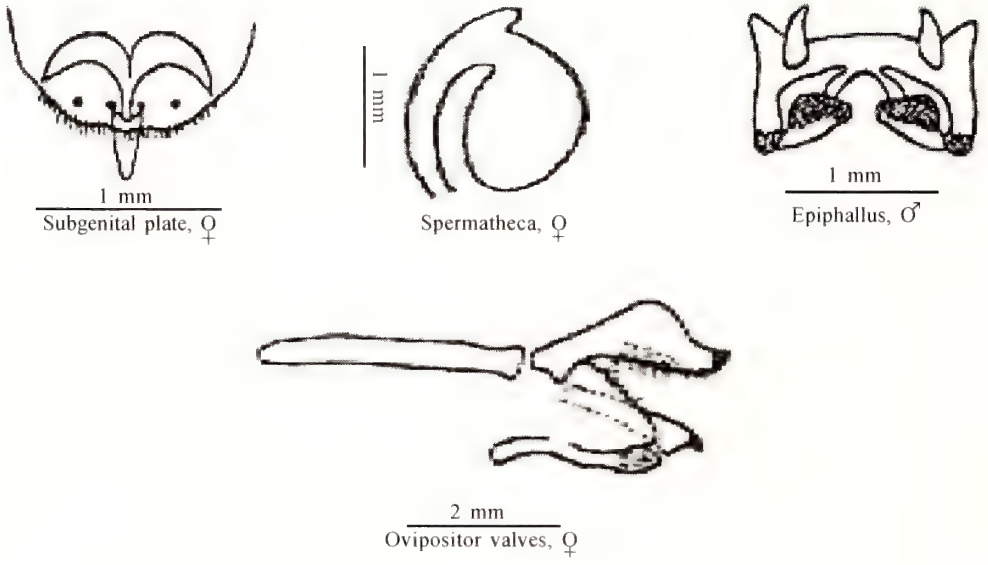

Fig. 5: ***Oedaleus senegalensis*** **(Krauss)**

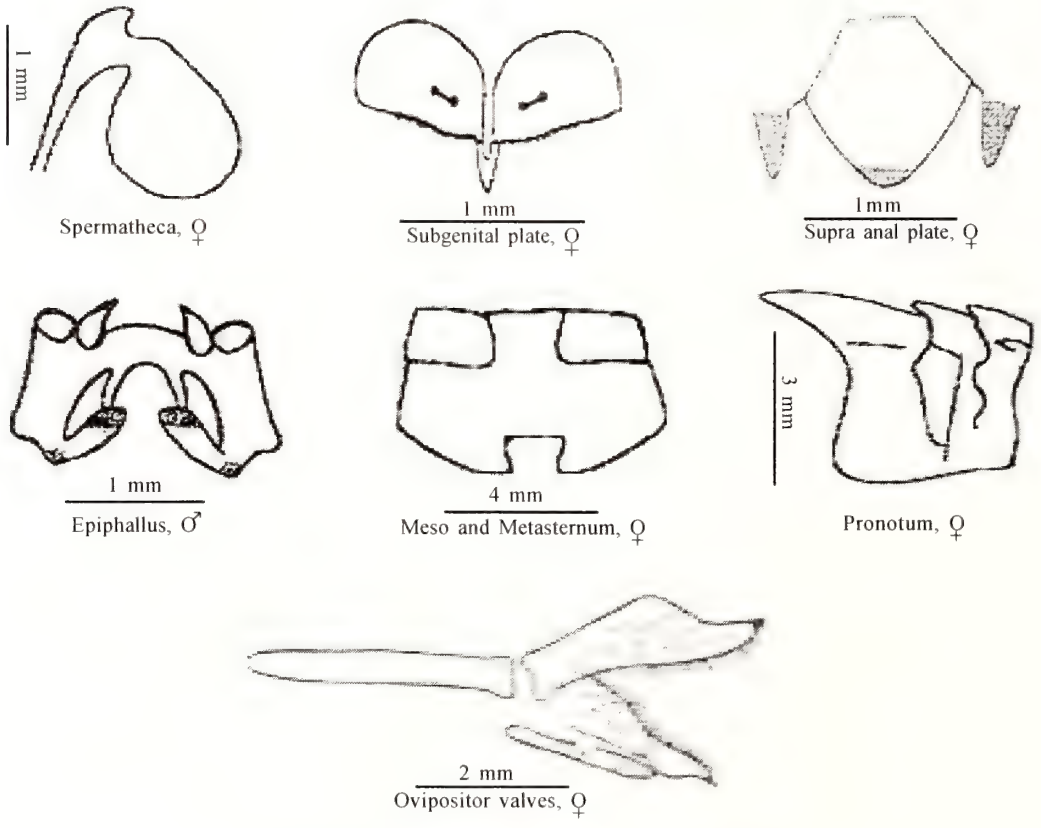

Fig. 6: ***Trilophidia annulata*** **(Thunberg)**

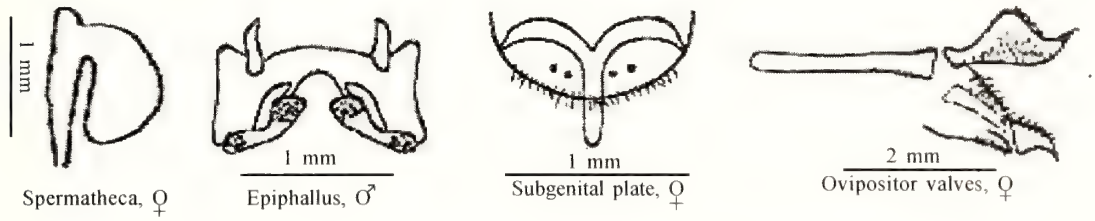

Fig. 7: *Acrotylus humbertianus* Saussure

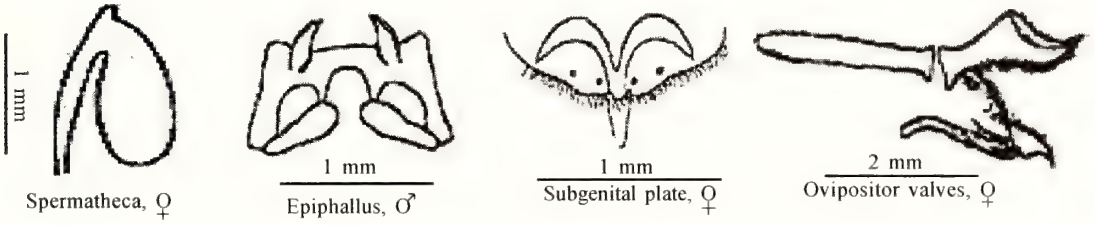

Fig. 8: *Aiolopus thalassinus* (Fabricius)

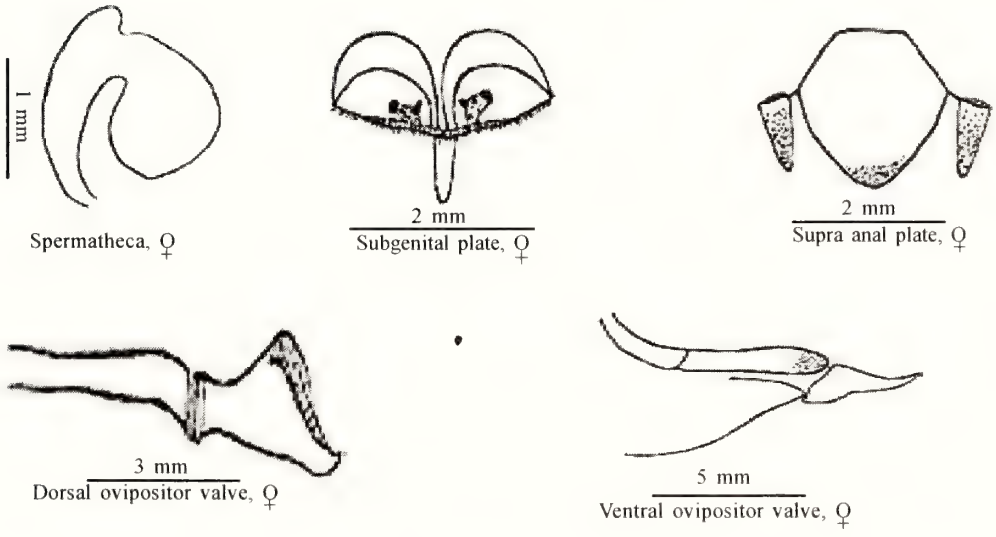

Fig. 9: *Dittopternis venusta* (Walker)

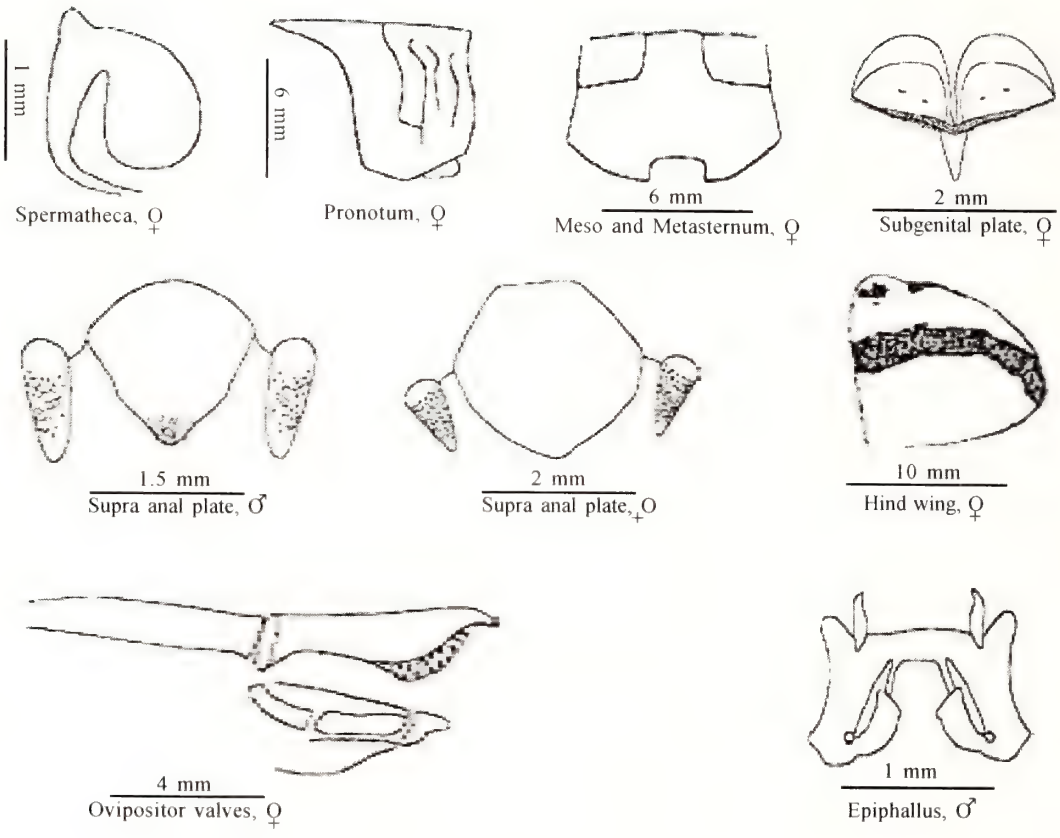

Fig. 10: *Gastrimargus africanus* Saussure

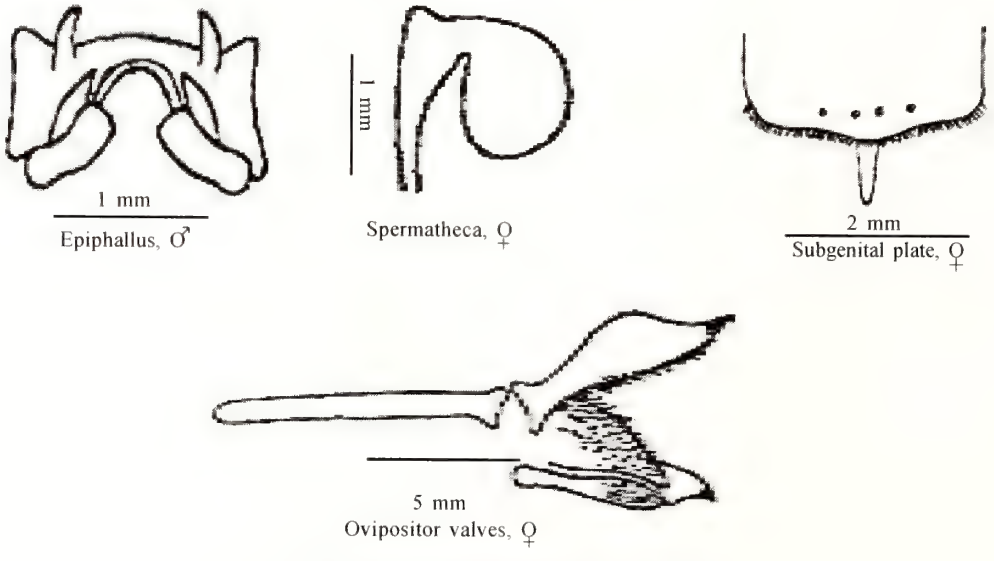

Fig. 11: *Locusta migratoria* Linn.

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Phylogenetic analysis of Indian species of genus *Macrophya* Dahlbom (Hymenoptera: Symphyta; Tenthredinidae: Tenthredininae)

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Abstract

Phylogenetic analysis was performed for 14 species of the genus *Macrophya* (Hymenoptera: Tenthredinidae) using the phylogenetic analysis package PAUP, based on 15 of the morphological characters most commonly used for *Macrophya* species identification. Species descriptions were derived primarily from "Indian Sawflies Biodiversity" vol. II (Saini 2007). Parsimony analysis, using equally weighted characters, produced 48 trees. The results are discussed in terms of evolutionary trends or biological maxim that "nature prefer to modify the already existing structures so as to cope with new needs."

Keywords: *Phylogenetic analysis, Macrophya, Evolutionary trends.*

Introduction

The genus *Macrophya* (Hymenoptera: Tenthredinidae) is widely distributed genus with its representatives available in almost all main regions of the globe. With regard to its affinities, it shares most of its characters with *Pachyprotasis* Hartig. Even within *Macrophya* the range of characters is so wide that time to time many of its subgenera were proposed (Malaise, 1945) and because of no distinct boundaries they all got merged (Ross, 1937 ; Gibson, 1980). Today none of its subgenus is considered to be valid (Abe & Smith,1991). The genus *Macrophya* was first described by Dahlbom (1835) as a subgenus of *Tenthredo* Linnaeus, on the basis of body shape, length and form of antenna. He divided this subgenus into two subsections "A" and "B". Hartig (1837) applied names to these two subsections using *T. (Macrophya)* for subsection "B" and *T.(M.) (Pachyprotasis)* for subsection "A". Both of these were later recognised as valid genera by Westwood (1840).

The genus is characterized by venation as in *Pachyprotasis,* but the anal cell may have a cross vein. Malar space mostly shorter than the diameter of an ocellus. The hind legs are strongly built, and the knees reaching and mostly exceeding the apex of the abdomen (Saini, 2007). The larval stages feed on variety of wild herbs, shrubs & trees. Generally adults feed on pollen, flower nectar or leaf juice exuding from wounds caused by strong mandibles. However, many robust species indulge in zoophagy (Cameron,1882; Rohwer,1913; Benson,1938; Malaise,1945; Naito,1988 and Goulet,1996).

The purpose of present study is to trace the long evolutionary history which modified generalizations into specializations of extreme form to suit the circumstances in which subsequently insects dwelled. Parsimony analysis is used to investigate phylogenetic relationships among *Macrophya* species, using data based on morphological characters most commonly used for *Macrophya* identification.

Materials and Methods

Species descriptions were derived primarily from "Indian Sawflies Biodiversity" vol.II (Saini, 2007) and the characters used in the

analysis were those given comparably for all, or almost all, species. *Tenthredo* Linnaeus was also included in the analysis as the outgroup.

Phylogenetic analysis was performed using the package PAUP version 3.1.1. (Swofford,1993). In total 15 morphological characters were used in the phylogenetic analysis. These were :-

1) Clypeus incision (0 = subsquarely incised, 1 = circularly incised, 2 = incised with irregular anterior margin, 3 = incised with truncate bottom, 4 = clypeus triangulary incised).
2) Anterior margin of labrum (0 = rounded, 1 = truncate, 2 = slightly emarginated).
3) Malar space (0 = shorter than diameter of an ocellus, 1 = longer than diamater of an ocellus, 2 = linear, 3 = inconspicuous).
4) Frontal area (0 = below level of eyes , 1 = at level of eyes).
5) Supraantennal tubercles (0 = raised, 1 = indistinct).
6) Median fovea (0 = broad and shallow, 1 = indistinct , 2 = absent).
7) Circumocellar furrow (0 = fine, 1 = distinct, 2 = indistinct).
8) Postocellar furrow (0 = indistinct, 1 = absent, 2 = distinct, 3 = fine).
9) Postocellar area (0 = flat, 1 = subconvex, 2 = raised).
10) Antenna length (0 = two times or more than two times of head width, 1 = antenna length less than two times of head width).
11) Mesoscutellum (0 = raised, 1 = sub convex, 2 = prismatic, 3 = flat, 4 = pulvinate).
12) Mesepisternum (0 = roundly raised, 1 = obtusely raised).
13) Subapical tooth of claw (0 = subapical tooth of claw longer than apical one, 1 = subapical tooth of claw is shorter than apical one, 2 = subapical tooth is subequal to apical one).

Table-1: Presence or absence data for fifteen characters for 14 species of the genus *Macrophya* as used in the phylogenetic analysis; *Tenthredo* Linnaeus is included as an outgroup.

Species	Character number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M. andreasi Saini and Vasu	1	0	2	1	1	0	0	0	1	1	0	1	0	1	4
M. brancuccii Muche	1	1	3	1	1	2	1	1	0	1	0	1	0	1	1
M. formosana Rohwer	1	1	0	1	0	1	0	3	1	1	0	0	2	1	4
M. gopeshwari Saini *et al.*	1	1	0	0	0	0	1	0	0	0	2	1	0	0	1
M. khasiana Saini *et al.*	0	1	3	0	0	0	1	0	1	1	0	1	0	1	1
M. maculicornis Cameron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M. manganensis Saini *et al.*	4	2	0	1	0	1	0	3	0	1	0	1	0	1	2
M. naga Saini and Vasu	1	0	1	1	1	1	1	2	1	0	4	1	0	1	4
M. planata Mocsary	2	0	0	0	0	1	2	0	1	0	2	1	0	1	2
M. pompilina Malaise	0	0	1	0	0	1	0	1	1	0	1	0	0	1	0
M. pseudoplanata Saini *et al.*	3	0	0	0	1	0	1	2	0	0	3	1	0	1	3
M. regia Forsius	0	1	0	0	1	2	0	1	2	1	0	0	0	1	0
M. rufipodus Saini *et al.*	1	1	0	1	0	1	1	1	0	0	1	0	0	1	1
M. verticalis Konow	1	1	0	0	0	2	1	1	0	1	0	1	1	1	0
Tenthredo Linnaeus	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0

14) Metabasitarsus (0 = as long as following joints combined, 1 = longer than following joints combined).

15) Wing appearance (0 = clear, 1 = hyaline, 2 = yellowish hyaline, 3 = dusky hyaline, 4 = smoky hyaline).

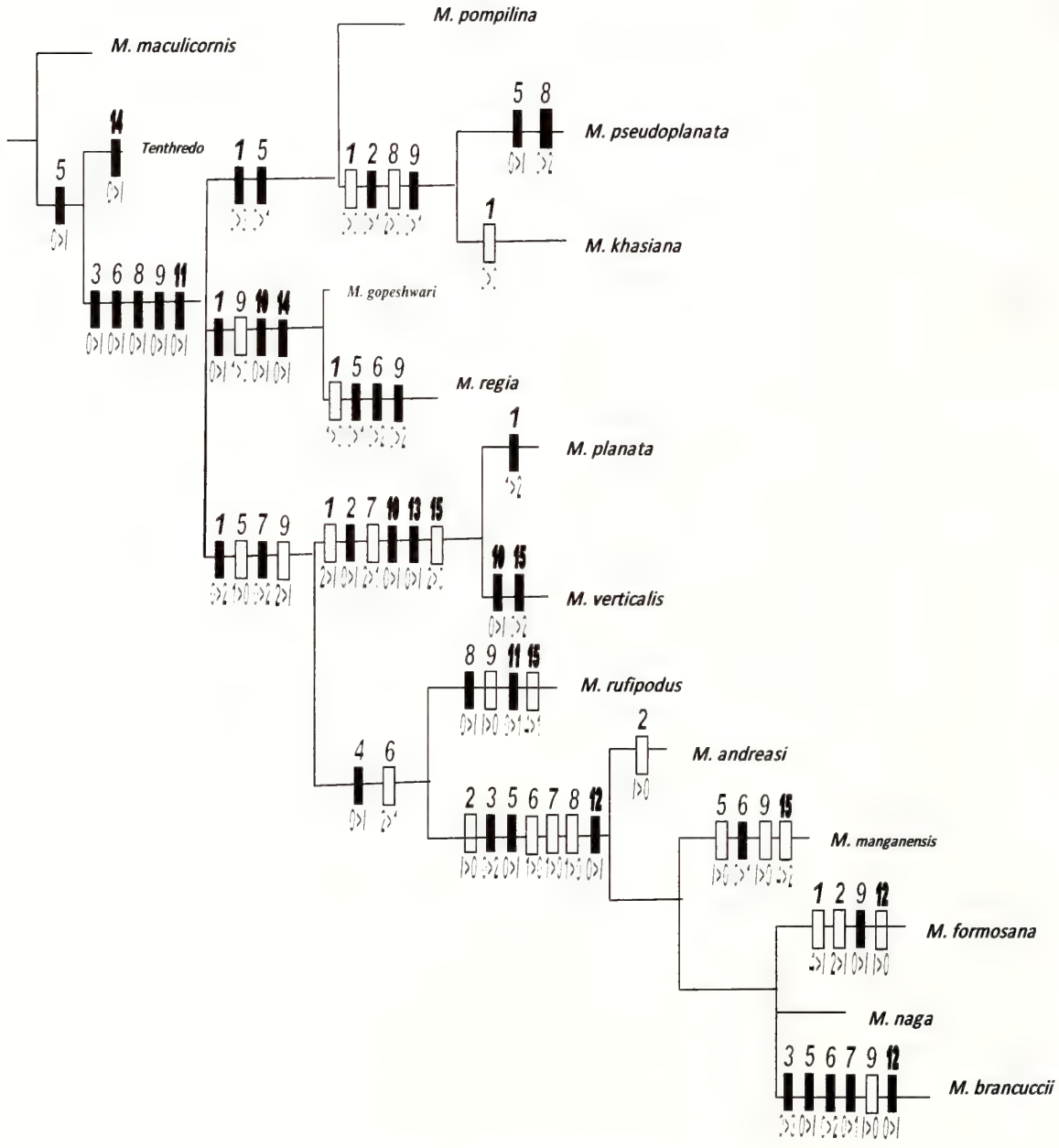

Fig. 1: Strict consensus tree for 14 species of *Macrophya* derived from the 48 most parsimonious trees calculated from the data in Table 1 ; outgroup = *Tenthredo* Linnaeus. Character of the ingroup have been optimized by fast transformation as implemented in PAUP. Character numbers are above the hashmarks; state changes are shown below with the respective primitive and derived conditions reported by a '>'. Apomorphy shown by filled hashmarks and pleisomorphy by open hashmarks.

Results

Parsimony analysis, using equally weighted characters, produced 48 most parsimonious trees (MPTs). Exact analysis by implicit enumeration (the 'i.e.' command of PAUP, which finds almost – parsimonious solutions) of the data in Table 1 resulted in formation of many cladograms which differed only at some places due to presence of more evolutionary events. Successive weighting was applied as a check of the reliability of the results. The main objective of phylogenetics is to correctly reconstruct the evolutionary history based on the observed character divergence between organisms. For estimating phylogenetic trees the most widely used PARSIMONY method (which hold the shortest tree to be the best estimate of the phylogeny) was used. Parsimony method is also called "Occam's Razor" after William of Occam, a 14th Century English philosopher who advocated this minimalist problem solving approach of "shaving away" unnecessary complications. The principle of maximum parsimony is to search for a tree that requires the smallest number of evolutionary changes to explain the differences observed among the OTU under study. As discussed by Goloboff (1991) the term parsimony is still regarded in two different ways by cladists:

1) as the principle of seeking the cladogram with the greatest explanatory power, given the weights the character deserve.

2) as the principle of seeking the cladogram with minimum length under equal weights.

Discussion

In Fig.1 *M. maculicornis* is separated from *Tenthredo* by character five and there occurs formation of derived or apomorphic character. Similarly, all characters shown in cladogram by which taxa are separated from one another and if there occurs formation of apomorphy then that character is shown by filled hashmarks and pleisomorphy by open hashmarks in the cladogram.

Tenthredo got separated from all other taxa by characters 3, 6, 8, 9 and 11 and there occurs formation of derived character and *M. pompilina* got separated from the latter by character 1 and character 5. Character 1 and character 5 both show apomorphy. So, sign 0>3 or 0>1 shows that there is formation of a derived character from the ancestral character. *M. pseudoplanata* and *M. khasiana* got separated from *M. pompilina* by characters 1, 2, 8 and 9. Similarly, *M. pseudoplanata* got evolved by character 5 and 8 and *M. khasiana* by character 1. *M. gopeshwari* and *M. regia* got separated by characters 1, 9, 10 and 14 and *M. regia* evolved due to characters 1, 5, 6 and 9. *M. planata*, *M. verticalis*, *M. rufipodus*, *M. andreasi*, *M. manganensis*, *M. formosana*, *M. naga* and *M. brancuccii* got separated from all above taxa by characters 1, 5, 7 and 9. *M. planata* and *M. verticalis* again separated from another by characters 1, 2, 7, 10, 13 and 15. The both taxa also got separated by some characters. *M. planata* by character 1 and *M. verticalis* by characters 10 and 15. *M. rufipodus*, *M. andreasi*, *M. manganensis*, *M. formosana*, *M. naga* and *M. brancuccii* got separated from *M. planata* and *M. verticalis* by characters 4 and 6. *M. rufipodus* got evolved due to character 8, 9, 11 and 15 and similarly, all other taxa got separated from other taxa due to presence of new characters present in them. So, extremely specialized forms descended by gradual changes leads to accumulation of certain appropriate features which represents body organization acquired to become complex so as to meet requirements which also underlies the biological maxim.

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Lucilia calviceps Bezzi, new record from India (Diptera: Calliphoridae), with a revised key to Indian species

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Abstract

Lucilia calviceps **Bezzi is newly recorded from India, a revised key is provided with all the Indian species.**

Keywords: *Lucilia calviceps, New record, India, Revised key.*

Introduction

Flies of genus *Lucilia* are generally called the green bottles. According to Kurahashi (1966) the genus *Lucilia* has been divided into three groups based on its evolutionary trends; i.e. *richardsi* group, *cluvia* group and *fumicosta* group. Out of these, the *richardsi* group is the most primitive (with maximum plesiomorph characters) and the *fumicosta* group being the most advanced one. The Indian fauna comprises of all the three groups but is dominated by Oriental elements (62.5%) followed by Palaearctic (25%) and Neotropical Nearctic (12.5%).

In Fauna of British India Diptera vi (Calliphoridae) by Senior White *et.al.,* (1940) genus *Lucilia* was represented by six species from India. At present this genus is represented by 8 species, *Lucilia bazini* seguy (Nandi, 2004) and *Lucilia calviceps* Bezzi being the new records from this region. The previous key (Senior White *et. al.,* 1940) is modified in order to incorporate the newly recorded species from India.

Key to the Indian species of *Lucilia*

1. Basicostal Scale Yellow, post sutural acrostichial 3 - (2)

----------Basicostal Scale brown or black; post sutural acrostichial 2 -(3)

2. Abdomen arched in profile; sternites with tuft of long hairs; hypopygium prominent; parafrontalia bare or almost bare except for frontals and fronts-orbitals in female - *Lucilia cuprina* (Wiedemann)

------------Abdomen not arched in profile, sternites without tuft of long hairs, hypopygium inconspicuous; parafrontalia in female with short decumbent bristles among frontals and parafrontals - *Lucilia sericata* (Meigen)

3. Alar squama always white or creamish in colour (never infuscated); lower squama may be white or infuscated - (4)

---------Alar squama and thoracic squama infuscated - (5)

4. Alar squama creamish with a tuft of yellowish white hairs at inner lower margin; thoracic squama pale, brownish on disc - *Lucilia bazini* seguy

---------Alar and thoracic squama predominantly white - - - - - - - - - - - - - - *Lucilia illustris* (Meigen)

---------Alar squama white; lower infuscated *Lucilia* ----------*ampullacea* Villeneuve

5. Anterior pair of post sutural acrostichial more advanced than 2nd pair of Post sutural dorsocentral- - - - - - - *Lucilia porphyrina* (Walker)

---------Anterior pair of Post sutural acrostichial on the level or slightly posterior than 2nd pair of post sutural dorsocentral - - ---------- (6)

6. Male frons broader than the distance between two posterior ocelli; female parafacialia broader than the width of 3rd antennal segment - - ---------- *Lucilia papuensis* Macquart

---------Male frons smaller than the distance between two posterior ocelli; parafacialia as broad as or narrower than the width of 3rd antennal segment in female ---------- (7)

7. Eyes in male separated at narrowest point by less than the width of anterior ocellus; parafacialia yellow – grey dusted, narrower than the width of 3rd antennal segment in female. ---- ---------- *Lucilia hainanensis* Fan

----------Eyes in male separated at narrowest point more than the width of anterior ocellus; parafacialia silver-grey dusted; as broad as width of 3rd antennal segment in female. ---------- ----------*Lucilia calviceps* Bezzi

***Lucilia calviceps* Bezzi**

Lucilia calviceps Bezzi, 1927:238. Type localites: Espiritu Santo and Epilsland, New Hebrides [Vanuatu] Length: 8.0-9.0 mm

Material Examined

India: 1 female, Gugga, UNA, Himachal Pradesh, 600.mts, 6.X.2009; 3 males Dharampur, Himachal Pradesh, 450mts, 14.X.2009; 1 male, Bari, Himachal Pradesh, 450mts, 15.x.2009; 1 male, Kotla, Himachal Pradesh, 470mts, 7.x.2009; 1 female, Kotla, Himachal Pradesh, 470mts, 7.x.09.

Distribution

India (Himachal Pradesh), Philippines (Luzon), Malaysia (Malaya, Borneo), Papua New Guinea, (New Guinea, New Britain, New Ireland, Bougainville I.), Vanuatu Loyalty Islands and New Caledonia.

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Impact of egg retention on walking behavior of *Trichogramma chilonis* (Hymenoptera: Trichogrammatidae)

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Abstract

In the present study effect of egg retention on walking behavior of females of *Trichogramma chilonis* (Hymenoptera: Trichogrammatidae) was investigated under laboratory conditions by using a computer based, Abid's trackmove software. Results revealed that 3 days old wasps showed significant increase in their walking activity for searching host eggs as compared to 1 day and 2 days old wasps respectively.

Keywords: *Trichogramma, Hymenoptera, Trichogrammatidae, Walking behaviour, Egg retention.*

Introduction

Egg parasitiods of genus *Trichogramma* are employed worldwide for biological control of insect pests (Smith, 1996). Searching for their host under natural conditions, long-range dispersal and delayed oviposition is often noticed in *Trichogramma* females (Wright *et al.,* 2001; Kuske *et al.*, 2003). In many field and laboratory studies recorded range of dispersal is even several meters (Brar *et al.,* 2000; McGregor *et al.,* 2000; Mehetre and Salunkhe, 2000; Wang *et al.,* 2000). For host oriented search, dispersal is mainly achieved by walking (Noldus *et al.,* 1991).

Egg retention or delayed oviposition is demonstrated as refusal to oviposit (Monje *et al.,* 1999; Silva and Stouthamer, 1999; Carriere and Boivin, 2001; Hoffmann *et al.,* 2001; Hansen and Jensen, 2002). Dissections and behavioral observations have showed that such females had a lot of mature ovarial eggs but parasitization was blocked at the stage of arrestment and host recognition (Pavlik, 1993; Reznik *et al.,* 1997, 1998). Earlier studies suggest that percentage of time spent in movement by *Trichogramma* females, delaying oviposition due to unavailability of suitable host eggs was slightly higher, than those for ovipositing females with readily available host eggs (Reznik and Umaraova, 1991).

In all previous studies movement activity was only recorded in the presence of host eggs. Thus the increase in time spent during movement could be assessed by time expenditure for parasitization. Besides host, stimuli also had a strong direct influence on the female's behavior (Gardner and Lenteren, 1986; Nordlund, 1994; Schmidt, 1994). Reznik *et al.*, (2001) demonstrated that oviposition by a group of simultaneously emerged *Trichogramma* females was observed to be uniformly distributed in time because of egg retention. Egg retention is thus accompanied with intensive movement activity and this mechanism seems to be even more adaptive when hosts are unavailable.

Relationships between walking behaviour and reproduction has never been investigated in the past. According to Dingle and Winchell (1997) spontaneous movement activity is better option for measure of dispersal. In view of this, present study has been designed to study walking behavior in females of *Trichogramma chilonis* during egg retention without providing host eggs.

Materials and Methods

Females of *Trichogramma chilonis* of age 1, 2 and 3 days were set to walk separately over specially designed grids made on an arena in order to observe their search for hosts (no host eggs were provided). Accuracy of the result depends upon size of grids. Smaller the grid size, accurate will be the results. Grids were numbered in a specific pattern on which computer operates the software (Abid's Trackmove). Grids on which data could be taken easily were selected and a transparent cover slip of 6.6 x 6.7cm with thin boundaries was used to avoid escape of wasps out of the grids. Each day 10 wasps were released singly and observation time for every replication was kept constant i.e. 3 minutes. As the wasps start moving over the grids, software was started and numbers of grids traveled were entered. The whole experiment was carried out under controlled laboratory conditions for temperature, humidity and uniform diet etc.

Results and Discussion

Table 1 shows that all the ten replications for 1 day old wasps have significantly less waking activity than those of 2 and 3 days old wasps respectively. The total distance covered and velocity attained by 2 days old wasps was higher than those of 1 day old ones and they even stayed for less time in the grids and their velocity without stay points was also greater. Same is the case with 3 days old wasps; they showed more higher velocity and covered more distance than those of 2 days old wasps. Their stay inside the gird was least and the velocity without stay points was maximum as compared to 1 day and 2 days old wasps.

Increased walking activity of *Trichogramma chilonis* wasps on each successive day was observed as to be a reaction for host search for parasitization and it increased with the passage of time due to egg retention resulting pressure build up in ovaries. Therefore, 3 days old wasps showed greater walking activity over 2 days and 1 day old wasps respectively.

Present study clarifies and confirms some queries of the previous studies, e.g. a study on the walking behaviour of *Trichogramma* females suggests that walking behavior of *Trichogramma* species (average speed, percentage of time spent moving etc.) and their movement only depends on environmental conditions, primarily on temperature (Fournier and Boivin 2000; Suverkropp *et al.,* 2001). However in the current study it was observed that physiological state of female can also be important. As all observations were collected under controlled conditions (temperature, humidity, diet, etc.) so difference in velocity and distance covered was observed as direct effect of egg retention. In another study with provision of non preferred hosts among preferred

Table-1: Walking behavior of *Trichogramma chilonis* females observed in relation to egg retention.

Replications (Wasps Released/Day)	Wasps Age	Observation Time	Total Distance Covered	Total Average Velocity	Velocity Without Stay	Total Stay Time
10	1 day	3 minutes	233.4 cm	2.013 cm/sec	3.216 cm/sec	43.29 sec
10	2 days old	3 minutes	274.2 cm	2.366 cm/sec	3.531 cm/sec	39.67 sec
10	3 days old	3 minutes	354.2 cm	2.94 cm/sec	3.804 cm/sec	23.41 sec

ones, it was observed that increase in movement and dispersal in parasitizing *Trichogramma* females was a direct consequence of their search for appropriate host. In accordance to it, present study without provision of any host eggs suggests that increased movement was due to the direct effect of pressure build up in ovaries of female wasps due to egg retention and in result of this, females accelerate their search for host eggs. Each next day this search was increased because the eggs get mature in the ovaries and were needed to oviposit at the earliest.

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Role of honeybees and other insects in enhancing the yield of *Brassica campestris* var. *sarson*

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Abstract

Qualitative and quantitative effects of pollination on fruit set; number of seeds per siliqua and mean weight of 100 seeds were compared in controlled and open pollinated plants of sarson. Percent fruit set, number of seeds per siliqua and mean seed weight of 100 seeds were significantly (P<0.01) higher in open pollinated viz., 8.09, 9.37 and 141.86 than in controlled ones. Moreover, seeds of open pollinated plants were larger in size and viable than controlled ones. The crop was visited by many insect pollinators but *Apis dorsata* followed by *Apis mellifera* and *Apis cerana* were observed to be the most common pollinating species.

Keywords: *Pollination, Brassica campestris* var. *sarson, Apis dorsata, A. mellifera, A. cerana.*

Introduction

Rapeseed mustard is the second most important edible oilseed crop in India after groundnut. Among rapeseed, *Brassica campestris* var. *sarson* is a self compatible crop and is generally considered to require insect pollination for better seed production (Mc Gregor, 1976; Free, 1970). These insects belong to orders viz., Hymenoptera, Diptera, Lepidoptera, Coleoptera and Thysanoptera (Michener, 1974). Of these, Hymenopterans are the most important agents because of their high energy requirements and tendency for collecting provisions for their brood in the form of pollen and nectar. It is considered that services rendered by bees in pollination of fruits, vegetables, legume and other seed crops are worth many times the return, which bee keepers receive in the form of honey and bee wax (Mattu *et al.*, 1994). Bees provide the most suitable conditions for pollen selectivity, thereby, increasing the viability, weight and germination of the seeds (Kozin, 1972). Alderman and Angelo 1933, also suggested the role of pollinating insects in getting good quality crops.

Materials and Methods

Studies were conducted at Hiranagar in district Kathua, Jammu division to know the qualitative and quantitative effects of pollination on sarson flowers in terms of fruit set, number of seeds per siliqua and seed weight (Verma and Partap, 1993).

Flowering started in the second week of January 2006.One colony each of *Apis cerana* F. and *Apis mellifera* L. were placed in the field when 15-20% of the flowering had already occurred. Plants with unopened floral buds were enclosed in insect mesh nets for self and wind pollination and open flower buds left for self pollination, pollination by wind and insects. Two sites were randomly selected in the field area having 10-12 plants, for each of the experimental designs as under:-

1) Affect of pollination on fruit set;

2) Affect of pollination on number of seeds per siliqua;

$$\frac{Number\ of\ fruits\ (Siliqua\ )}{Number\ of\ buds} X\ 100$$

The number of seeds per siliqua was counted before harvesting period.

3) Affect of honeybees and other insect on fruit quality;

Qualitative effect of honeybees and other insect pollinators on fruit quality was studied by collecting the ripe seeds. It was assessed in terms of increase in weight of seeds, measured with the help of micro electric balance. For this, 100 seeds were collected from each experimental design and mean weight of 10 samples with 100 seeds was found. The data so obtained was analyzed statistically.

Results and Discussion

Seed yield data so obtained is presented in the Table 1, which reveals that fruit set was 79.96% in controlled experiment, while it was 88.05% in open pollinated flowers. This shows an increase of 8.09% in open pollinated flowers as compared to controlled ones. Similarly, mean number of seeds/siliqua was 10.24 and 11.20, while mean weight of 100 seeds was 0.172 and 0.416 gm in controlled and open pollinated experimental designs respectively. These figures show an increase of 9.37% of seeds/siliqua and 141.86% of mean weight of 100 seeds in open pollinated flowers than controlled ones.

These results are in conformity with the already recorded observations of Chand and Singh (1995) on *Brassica juncea* and Mishra *et al.* (1988) on *Brassica campestris* var. *sarson.*

Further, Khan and Chaudhary (1988) emphasized upon the view that insect pollination led to the formation of well shaped larger grains and more viable seeds than self pollinated plants. The present investigator, also reconfirms these observations of the *op. cit.* workers, where the seeds of open pollinated plants are larger and viable than net caged ones. Some similar observations were reported by Singh (1997) on *Brassica juncea* and Singh *et al.*, (2004) on var. *toria.*

Table-1: Qualitative and quantitative effect of open pollination upon control pollination of plants of *Brassica campestris* var. *sarson

Parameter	Control	Open pollinated	Per cent Increase*
Fruit set	79.96	88.05	8.09
Number of seeds per siliqua	10.24	11.2	9.37
Weight (g)	0.172	0.416	141.86

*= Open pollinated > control ($P < 0.01$)

Conclusion

Qualitative and quantitative data reveals significant ($P<0.01$) increase in percent of fruit set, number of seeds/siliqua and mean weight of 100 seeds in open pollinated flowers than in controlled flowers, covered with muslin cloths. Thus insects, especially the bees are the cheapest source for increasing the yield of oilseed crops.

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Diversity of Aphidoidea in Rawalpindi Division (Punjab) Pakistan, with a list of host plant studied

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Abstract

Aphids were collected from different hosts in four districts of Rawalpindi Division (Punjab), Pakistan. A total of 700 specimens were collected, yielding eight species under eight genera. Details regarding valid names, body size, distribution and general body characters of collected specimens alongwith their host plants are discussed in this paper. Richness and abundance of species was also studied. Further surveys are needed to unhide the existing fauna of Aphidoidea from the area.

Keywords: *Diversity, Aphidoidea, Pakistan, Punjab, Rawalpindi.*

Introduction

Aphidoidea includes small soft bodied insects, commonly called aphids, blackflies, plant lice or greenflies. They are serious pests of crops, vegetables, ornamental plants and fruits. They suck cell sap and inject toxic saliva into plant tissues which may result in curling of leaves, appearance of discoloured spots on the foliage, blighting of buds and dimpling of fruits (Hashmi, 1994). Honey dew is released on plant leaves which results in development of sooty mould which hinders its photosynthesis (Blackman and Eastop, 2000).

In Pakistan, lot of work has been done on the biology and population dynamics of aphids but only fewer taxonomic studies were carried out uptill now. Taxonomy of Aphidoidea in Pakistan was studied by Das (1918), Munir (1953), Khaliq (1965), Awan (1973) and Nasir (1989). A need for comprehensive survey was felt and present study was under taken to make an authentic and updated record of Aphidoidea inhabiting Rawalpindi division of Punjab province, Pakistan.

Materials and Methods

Extensive sampling was done during the years (2007–2008) to collect adults of Aphidoidea. All the four districts i.e Rawalpindi, Chakwal, Jehlum and Attock with twenty localities (five from each district) were visited (Fig. 1). Details of collection sites is as follows:-

Rawalpindi Division (Punjab):

1) District Rawalpindi: Kahuta (L1), Mandra (L2), Gujar Khan (L3) Taxila (L4), Islamabad {NARC Research Farms (L5)}.
2) District Chakwal: Talagang (L6), Choa Syedan Shah (L7), Kallar Kahar (L8), Tman (L9), Mogla (L10).
3) District Jehlum: Dina (L11), Sohawa (L12), Mangla (L13), Pind Dadan Khan (L14), Khewra (L15).
4) District Attock: Hazro (L16), Hassan Abdal (L17), Fateh Jang (L18), Pindi Gheb (L19), Jand (L20).

Aphids were collected from cereal crops, grasses, vegetables, weeds and fruit trees with an ordinary camel hair brush, by jerking the plants on white paper sheet and by netting in some cases. Their search was followed by deep observation of symptoms on plants such as presence of coccinellids and other aphid predators, ant associations, rolling and yellowing of infested leaves and development of black sooty mold. They were brought to the laboratory of National Insect Museum and were preserved in 80% alcohol. After making their slides, specimens were identified following Eastop (1961), Stroyan (1977), Martin (1983), Blackman and Eastop (1994); and Blackman and Eastop (2000). Voucher specimens were deposited in National Insect Museum, NARC– Islamabad.

Results and Discussion

Thirteen different hosts grown in twenty five different localities of four districts of Rawalpindi division were sampled to collect adults of Aphidoidea. A total of 700 adult aphids were collected that provides a record of eight aphid species identified under eight genera. Details regarding valid names, body size, distribution, general appearance and host plants for collected species are presented (Table 1).

Richness of species was observed (Fig. 2), which shows presence of all the eight species in Rawalpindi district. However minimum number of species i.e five species were recorded from district Jehlum. Abundance of species was also studied (Table 2) showing *Lipaphis erysimi, Brevicoryne brassicae and Rhopalosiphum padi* as dominant and abundant species of Rawalpindi district and *Sitobion avenae and Metopolophium dirhodum* as common species of Jehlum district. However *Brevicoryne brassicae* also appeared to be a prevalent species of district Attock. *Prociphilus oleae* appears to be very rare and was recorded only from a single locality of Rawalpindi district. Due to huge diversity in topography and flora of the area, further surveys can add more species of Aphidoidea.

To study the diversity of Aphidoidea in each area, diversity index following Menhinick (1964) was calcultaed (Fig. 3) which shows highest aphid diversity in district Chakwal however minimum was calculated for Attock. District Chakwal is rich in flora and almost all the major crops and a wide variety of vegetables and grasses are grown here, which may be a possible reason for higher aphid diversity in this area. In contrast to this Jhelum is less fertile and more mountainous as compared to Chakwal, which favours less development of Aphidoidea due to host unavailability.

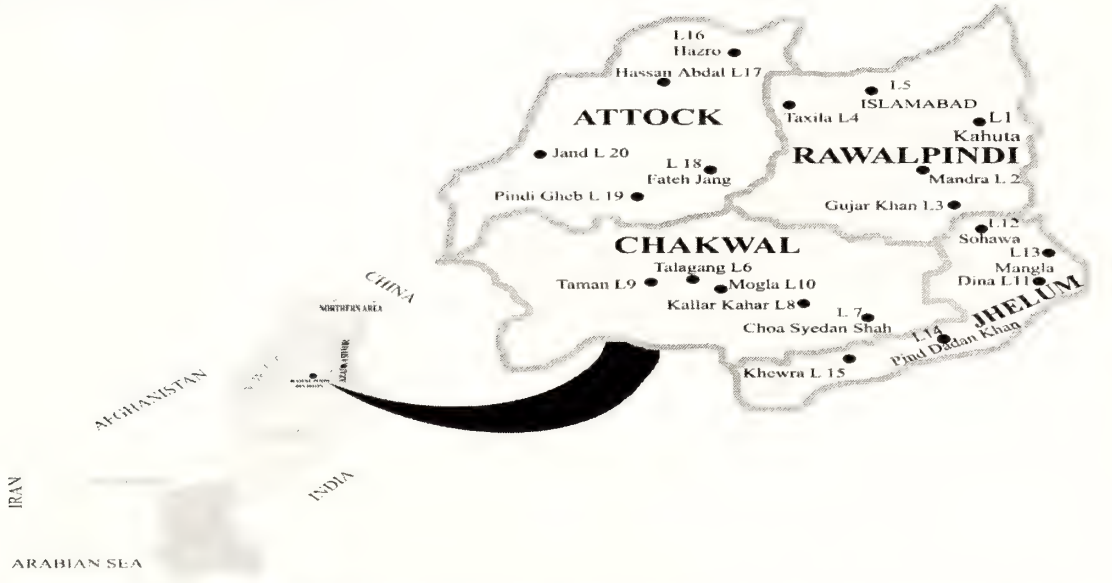

Fig.1 : Map of Pakistan showing Rawalpindi Division with its four districts along with sites of collection for Aphidoidea.

Table-1: Details regarding collected Aphidoidea of Rawalpindi Division (Punjab), Pakistan.

S.No.	Scientific Names	Measurement	General Appearance	Distribution	Host Plant Studied
1.	*Acrythosiphon pisum* (Harris, 1776)	Apterate: 2.3–4.3mm Alatae: 2.5–4.4mm	Greenish to pink colour, with slendrical appendages.	L4, L5, L10, L16, L17.	Pea plants (*Pisum sativum*).
2.	*Aphis gossypii* (Glover, 1925)	Apterate: 1.0–1.8mm Alatae: 1.2–1.8mm	Dark green to almost blackish in old specimens, however pale yellow to whitish under crowded colonies. Siphunculi darker with cauda pale in appearance.	L5, L16, L17.	Guava *(Psidium guajava),* Potato *(Solanum tuberosum).*
3.	*Brevicoryne brassicae* (Linnaeus, 1758)	Apterate: 1.6–2.6mm Alatae: 1.6–2.8mm	Greyish green to dull mild green with head and dorsal markings on thorax and abdomen darker. Body is medium sized covered with greyish white mealy wax.	L1, L3, L4, L5, L8,L14, L16, L17, L18, L20.	Cabbage and Cauliflower (*Brassica oleracea*), Radish (*Raphanus sativus*), Mustard (*Brassica campestris*).
4.	*Lipaphis erysimi* (Kaltenbach,1843)	Apterate: 1.4–2.4mm Alatae: 1.4–2.2mm	Yellowish green to duskey green or grey green in colour. Coated with wax under humid conditions. Dark conspicuous sclerites present on abdomen laterally.	L2, L3, L4, L5, L6, L9, L10, L11, L14, L18, L19, L20.	Mustard (*Brassica campestris*), Wheat (*Triticum aestivum*), Maize (*Zea mays*).
5.	*Metopolophium dirhodum* (Walker, 1849)	Apterate: 1.6–2.9mm Alatae: 1.6–2.3mm	Green or yellowish green, with bright green longitudinal mid dorsal stripes. Body is elongated spindle shaped	L4, L5, L6, L9, L13, L15, L16, L18, L20.	Rose plantantions, Wheat (*Triticum aestivum*), Sudan grass (*Sorgum sudanensis*), Baru (*Sorghum helipense*).

Table-1: continued.

S.No.	Scientific Names	Measurement	General Appearance	Distribution	Host Plant Studied
6.	*Prociphilus oleae* (Leach ex Risso, 1826)	Apterate: 1.8–3.0mm Alatae: 1.7–2.9mm	Greenish to darker in colour, elongated, with hind tarsi greatly elongate, siphunculi present as flat pigmented cone.	L5.	Olive plantations (*Olea europea*).
7.	*Rhopalosiphum padi* (Linnaeus, 1758)	Apterate: 1.5-2.1mm Alatae: 1.6-2.0mm	Molted yellowish green, olive green, greenish black. Small to medium sized with broadly oval shaped body.	L2, L3, L4, L5, L6, L9, L10, L11, L14, L18, L19, L20.	Sudan grass (*Sorgum sudanensis*), Baru (*Sorghum helipense*), Khabal grass (*Cynodon dactylon)*, Mustard (*Brassica campestris*), Wheat (*Triticum aestivum*), Maize (*Zea mays*), Sorghum (*Sorghum vulagare*).
8.	*Sitobion avenae* (Fabricius, 1775)	Apterate: 1.3–3.3mm Alatae: 1.6–2.9mm	Yellowish green, dirty reddish brown to shiny reddish brown, uniform sclerites present on dorsal side of abdomen.	L1, L4, L5, L7, L9, L10, L11, L12, L13, L15.	Sudan grass (*Sorgum sudanensis*), Baru (*Sorghum helipense*), Maize (*Zea mays*), Millets (*Pennisetum glaucum and P. typhoides*), Mustard (*Brassica campestris*), Wheat (*Triticum aestivum*), Rice (*Oryza sativa*).

Table-2: Abundance of Aphidoidea in Rawalpindi Division (Punjab), Pakistan.

Species Recorded	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20
Acrythosiphon pisum (Harris, 1776)	-	-	-	+	+	-	-	-	-	+	-	-	-	-	-	+	+	-	-	-
Aphis gossypii (Glover, 1925)	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Brevicoryne brassicae (Linnaeus, 1758)	+	-	+	+	+	-	-	+	-	-	-	-	-	+	-	+	+	+	-	+
Lipaphis erysimi (Kaltenbach, 1843)	-	+	+	+	+	+	-	-	+	+	+	-	-	+	-	-	-	+	+	+
Metopolophium dirhodum (Walker, 1849)	-	-	-	+	+	+	-	-	+	-	-	-	+	-	+	+	-	+	-	+
Prociphilus oleae (Leach ex Risso, 1826)	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhopalosiphum padi (Linnaeus, 1758)	-	+	+	+	+	+	-	-	+	+	+	-	-	+	-	-	-	+	+	+
Sitobion avenae (Fabricius, 1775)	+	-	-	+	+	-	+	-	+	+	+	+	+	-	+	-	-	-	-	-

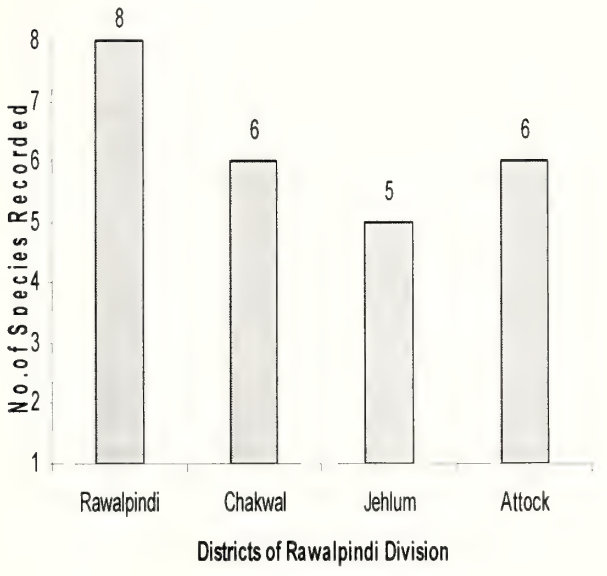

Fig. 2: Richness of Aphidoidea in Rawalpindi Division (Punjab), Pakistan.

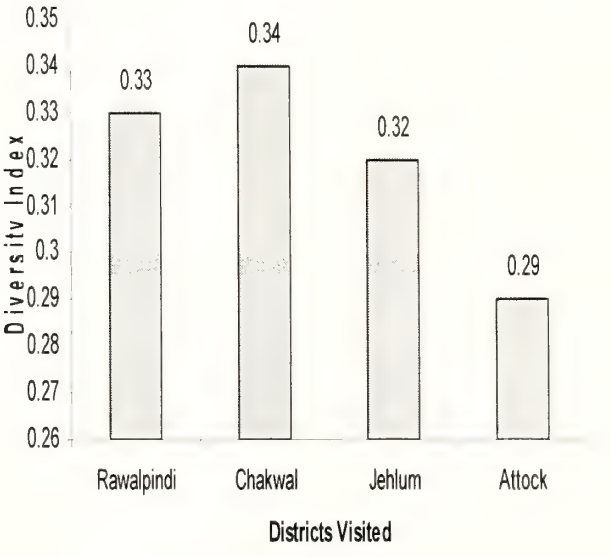

Fig. 3: Diversity Index Calculated

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Phylogenetic analysis of Indian species of genus *Himalopsyche* Banks (Trichoptera: Spicipalpia; Rhyacophilidae: Rhyacophilinae)

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Abstract

Phylogenetic analysis was conducted for 19 species of the genus *Himalopsyche* (Trichoptera: Rhyacophilidae) using the phylogenetic analysis package PAUP, based on 12 of the morphological characters most commonly used for *Himalopsyche* species identification. Species descriptions were primarily taken from literature contributed by Morton (1900), Martynov (1930, 1935, 1936), Kimmins (1952) and Schmid (1963,1966). Parsimony analysis, using equally weighted characters, produced 27 trees and the strict consensus tree derived from these identified two groupings are to be present in all 27 trees. The results are discussed in terms of evolutionary trends or remarkable diversity of genitalic types in the males.

Keywords: *Phylogenetic analysis, Trichoptera, Himalopsyche, Genitalic types.*

Introduction

The small genus *Himalopsyche* originated in the Oriental region and was first described by Banks (1940). All the species occur in Oriental region with exception of *H. phryganea* (Schmid,1989) which is distributed in North America. So all species except *H. phryganea* are thought to have been designated as endemic Oriental species. From the Oriental region this genus is represented by 38 species out of which 19 are from India alone. Indian species are mainly contributed by Morton (1900), Martynov (1930,1935,1936), Kimmins (1952) and Schmid (1963,1966) to the tune of 1,3,2 and 13 species respectively. On the basis of so many morphological affinities this genus is closely related to *Rhyacophila,* of which it seems to be a specialized off shoot.

When viewed from the economic point of view, larvae of this group are important and beneficial components of the trophic dynamics and energy flow in the lakes, rivers and streams they inhabit (Resh and Rosenberg, 1984). This group is considered the most useful and important aquatic organisms for monitoring climatic changes and are widely used in bio monitoring surveys. Parsimony analysis is used to investigate phylogenetic relationships among *Himalopsyche* species, using data based on morphological characters most commonly used for *Himalopsyche* identification.

Materials and Methods

Species descriptions were derived primarily from literature contributed by Morton (1900), Martynov (1930,1935,1936), Kimmins (1952) and Schmid (1963,1966) and the characters used in the analysis were those given comparably for all, or almost all, species. *Rhyacophila* Pictet was also included in the analysis as the outgroup.

Phylogenetic analysis was performed using the package PAUP version 3.1.1. (Swofford, 1993). In total 12 morphological characters were used in the phylogenetic analysis. These were:-

1) Inferior appendage (0= uniarticulated, 1= biarticulated).
2) Preanal appendage (0=completely fused with segment X, 1= free from segment X).

3) Anterior Claw (0 = symmetrical, 1 = asymmetrical).
4) Preanal appendage (0= present, 1= absent).
5) Anal Sclerite (0= pointed and narrowing towards apical end, 1= rounded and blunt towards apical end).
6) Anal Sclerite (0= apically bifid, 1= apically not bifid).
7) Median lobes of segment X (0= partly fused, 1 = completely fused at $\frac{2}{3}$ of their length).

Table 1: Presence or absence data for twelve characters for 19 species of the genus *Himalopsyche* Banks as used in the phylogenetic analysis; *Rhyacophila* Pictet is included as an outgroup.

Species	Character number											
	1	2	3	4	5	6	7	8	9	10	11	12
Himalopsyche amitabha Schmid 1966	0	0	0	1	1	1	1	1	1	0	1	1
Himalopsyche angnorbui Schmid 1963	0	0	0	1	1	1	1	1	1	0	1	0
Himalopsyche bhagirathi Schmid 1963	0	0	0	0	1	1	1	1	0	1	1	0
Himalopsyche biansata Kimmins 1952	1	1	1	1	1	1	1	1	1	0	1	1
Himalopsyche digitata Martynov 1935	1	1	1	1	1	1	1	1	1	0	1	1
Himalopsyche dolmasampa Schmid 1963	0	0	0	0	0	1	0	0	1	1	1	0
Himalopsyche gyamo Schmid 1963	0	0	0	0	1	1	1	1	1	0	0	0
Himalopsyche hierophylax Schmid 1966	1	1	1	1	1	1	1	1	1	0	0	0
Himalopsyche horai Martynov 1936	1	1	1	1	1	1	1	1	1	0	1	1
Himalopsyche lanceolata Morton 1900	1	1	1	1	1	1	1	1	1	1	1	1
Himalopsyche lepcha Schmid 1963	1	1	1	1	1	1	1	1	1	0	0	0
Himalopsyche lungma Schmid 1963	0	0	0	0	1	1	1	1	1	0	1	0
Himalopsyche maitreya Schmid 1963	1	1	1	1	1	1	1	1	1	0	1	1
Himalopsyche malenanda Schmid 1963	0	0	0	0	0	1	1	1	1	0	1	1
Himalopsyche phedongensis Kimmins 1952	1	1	1	1	1	1	1	1	1	0	0	0
Himalopsyche tibetana Martynov 1930	1	1	1	1	1	1	1	1	1	0	1	1
Himalopsyche todma Schmid 1963	0	0	0	0	0	0	0	0	0	0	0	1
Himalopsyche yatrawalla Schmid 1966	0	0	0	0	1	1	1	1	1	1	1	1
Himalopsyche yongma Schmid 1963	0	0	0	0	1	1	1	1	1	1	1	0
Rhyacophila Pictet 1834 (Outgroup)	0	0	0	0	0	0	0	0	0	0	0	0

8) Anal sclerite (0= Anal sclerite with long root invaginated upto half of segment IX, 1 = Anal sclerite with short root not invaginated into segment IX).

9) Segment IX (0= quite prominent forms a roof over segment X, 1 = reduced does not form a roof over segment X).

10) Paramere (0= absent, 1= present).

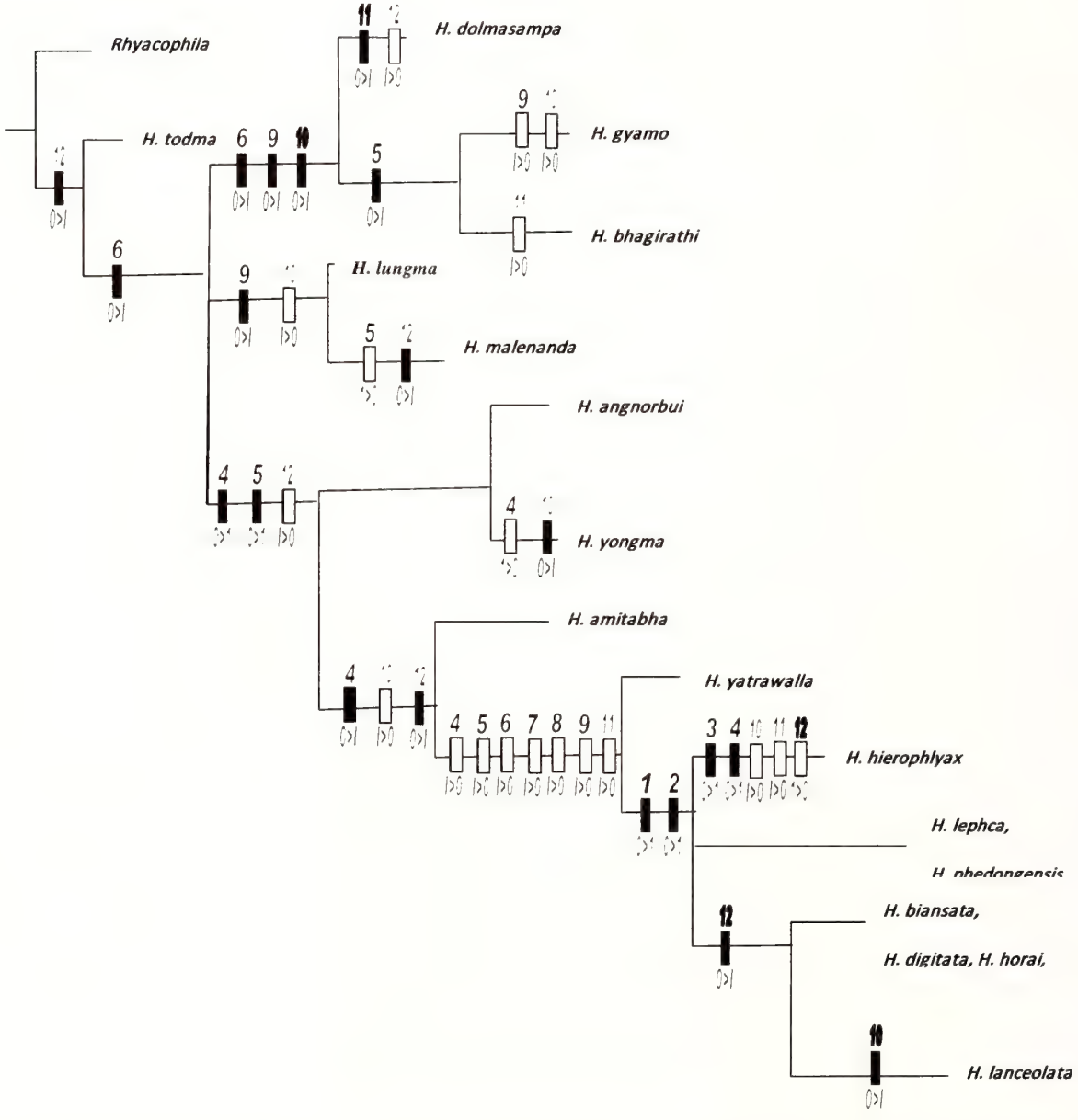

Fig. 1: Strict consensus tree for 19 species of *Himalopsyche* derived from the 27 most parsimonious trees calculated from the data in Table 1; outgroup = *Rhyacophila* Pictet. Character of the ingroup have been optimized by fast transformation as implemented in PAUP. Character numbers are above the hashmarks; state changes are shown below with the respective primitive and derived conditions reported by a '>'. Apomorphy shown by filled hashmarks and pleisomorphy by open hashmarks.

11) Scape to pedicel ratio (0= If scape length is less than half of pedicel length, 1= If scape length is more than half of pedicel length).

12) IATS : MB : OATS* (0= If MB ratio greater than IATS but smaller than OATS, 1= If MB ratio smaller than IATS but greater than OATS).

*** IATS–Inner Apical Tibial spur, MB-Meta basitarsus, OATS–Outer Apical Tibial Spur**

Results

Parsimony analysis, using equally weighted characters, produced 27 most parsimonious trees (MPTs). Successive weighting was applied as a check of the reliability of the results. The main objective of phylogenetics is to correctly reconstruct the evolutionary history based on the observed character divergence between organisms.

For estimating phylogenetic trees the most widely used PARSIMONY and MAXIMUM LIKELIHOOD methods were used. Parsimony method also known as " Occam's Razor" after William of Occam, a 14th century English Philosopher who advocated this minimalist problem solving approach of "shaving away" unnecessary complications and the principle of maximum likelihood, is a tree with the highest likelihood and is the best estimate of the true phylogeny. The species *Himalopsyche todma* differs from all other species of *Himalopsyche* by the single character of apically bifidation of anal sclerite (character 6). To further investigate the MPTs the majority rule consensus method was used.

Discussion

In Fig.1 *H. todma* got separated from *Rhyacophila* by character 12 and *H. todma* differed from all other species of *Himalopsyche* due to apically bifidation of anal sclerite. Similarly, all characters are shown in cladogram by which taxa got separated from one another. The derived consensus tree identified two groupings to be present in the cladogram. The first group was composed of two unique species *H. gyamo and H. bhagirathi*. They grouped on the basis of shape of anal sclerite.The second group contained nine species *H. hierophylax, H. lepcha, H. phedongensis, H. biansata, H. digitata, H. horai, H. maitreya, H. tibetana* and *H. lanceolata*. They clustered together due to biarticulation of inferior appendage. *H. dolmasampa* got separated from *H. todma* by characters 6, 9 and 10. All characters showed apomorphy. So sign 0>1 showed that there was formation of derived character from ancestral character. *H. gyamo* and *H. bhagirathi* got separated from *H. dolmasampa* by character 5. *H. gyamo* got evolved by characters 9 and 10 and *H. bhagirathi* by character 11. *H. lungma* and *H. malenanda* got separated by characters 9 and 10. Character 9 showed apomorphy and character 10 showed pleisomorphy. *H. malenanda* got evolved due to characters 5 and 12. Character 12 showed maximum evolution. *H. angnorbui* and *H. yongma* got separated from *H. malenanda* by characters 4, 5 and 12. *H. yongma* got evolved by characters 4 and 10. *H. amitabha* got separated from latter by characters 4, 10 and 12. Similarly, *H. yatrawalla* got separated from *H. amitabha* by characters 4, 5, 6, 7, 8, 9 and 11. All the characters showed pleisomorphy. *H. hierophylax* got separated from *H. yatrawalla* due to presence of characters 1 and 12 and got evolved by characters 3, 4, 10, 11 and 12. Only the characters 3 and 4 showed apomorphy. *H. lepcha* and *H. phedongensis* got separated from *H. hierophylax* but they both shared the same characters. *H. biansata, H. digitata, H. horai, H. maitreya* and *H. tibetana* got separated from *H. phedongensis* by character 12 and they all shared the same characters but *H. lanceolata* developed new character 10 and got separated from *H. biansata, H. digitata, H. horai, H. maitreya* and *H. tibetana*. To conclude, this can be said that species of genus *Himalopsyche* Banks exhibit a remarkable diversity of genitalic types in the males.

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Influence of foraging rate and speed of *Apis* species (Hymenoptera) on *Brassica campestris* var. sarson

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Abstract

Foraging rate and speed of three species of *Apis cerana, A. mellifera* and *A. dorsata* were studied in the fields of sarson at Pallimore and Hiranagar at three different hours of the day viz., 0900, 1200 and 1500 hours in order to determine the number of flowers visited per bee at a particular time. At both Pallimore and Hiranagar, *A. dorsata* spent significantly more time than *A. cerana* and *A. mellifera* at 0900hours, whereas no significant (P>0.05) differences were observed between the three *Apis* species at 1200 and 1500 hours of the day. However number of flowers visited/bee/minute by *A. mellifera* were significantly (P<0.05) more than *A. dorsata* and *A. cerana* at 0900 and 1200 hours at Pallimore but no such significant differences (P>0.05) were observed at 1500 hours of the day. Similarly at Hiranagar, *A. mellifera* visits significant (P<0.05) number of flowers/ minute at 1200hours than *A. dorsata* and *A.cerana,* whereas at 0900 and 1500 hours no such significant differences were observed (P>0.05).

Keywords: *Apis cerana, Apis mellifera, Apis dorsata, Brassica campestris, Foraging.*

Introduction

Insects are of prime significance in pollination of agricultural and horticultural crops.These insects belong to order Hymenoptera, Diptera, Lepidoptera, Coleoptera and Thysanoptera (Michener, 1974). Among hymenoptera, honeybees are considered as the most efficient pollinators of cultivated crops because of their floral fidelity (Wells and Wells,1983 and Waser, 1986), potential for long working hours (Sihag, 1990), presence of pollen baskets, maintainability of high population, micromanipulation of flowers and adaptability to different climatic conditions (Verma and Partap,1993).

Materials and Methods

Time spent per flower and number of flowers visited per minute were taken as the indicators of foraging rate and speed respectively. Time spent by a worker bee of *A.cerana* and *A. mellifera* on sarson flower and number of flowers visited per minute was recorded with the help of a stop watch having an accuracy of one tenth (1/ 10^{th}) of a second. These observations were taken thrice a day at 0900, 1200 and 1500 hours and were repeated for a week in each field under good climatic conditions.

Results and Discussion

Three species of *Apis* were monitored for their foraging rate and speed at three different hours of the day i.e. 0900, 1200 and 1500 hours at both the fields as shown in Table 1 and Figures 1, 2, 3 & 4. It reveals that *Apis cerana* and *A. mellifera* coincide in their foraging rate and speed at 0900, 1200 and 1500 hours i.e. there is no difference in their foraging rate and speed. For *A. dorsata* the foraging rate and speed remains the same at 1200 and 1500 hours but at 0900 hours *A. dorsata* spent more time than *A. cerana* and *A. mellifera*. This may be due to large body size of *A. dorsata* and also due to partial opening of the flowers in the morning hours.

These results are in agreement with Verma and Partap (1993) who noted no significant differences in the time spent and number of flowers

Table -1: Time spent per flower per bee (seconds) and number of flowers visited per bee/minute on sarson bloom at Pallimore and Hiranagar, district Kathua.

Fields	Parameters		0900 hr			1200 hr			1500 hr		
			A.c.	*A.m.*	*A.d.*	*A.c.*	*A.m.*	*A.d.*	*A.c.*	*A.m.*	*A.d.*
Pallimore	(a)Time spent/bee/ flower(sec)	X±S.E	2.44±0.27	2.82±0.22	4.21±0.34	2.34±0.26	2.36±0.23	2.87±0.15	2.18±0.12	2.36±0.17	2.47±0.15
		C.V.	29.51	20.57	21.19	29.06	25.55	14.04	14.68	19.49	15.79
	(b) No.of flowers visited/bee/ minute	X±S.E	11.57±0.32	12.91±0.84	10.20±0.26	12.48±0.44	13.31±0.33	11.31±0.37	13.00±0.43	13.68±0.37	12.11±0.63
		C.V.	7.17	17.12	6.86	9.29±	6.54	8.66	8.77	7.09	0.63
Hiranagar	(a)Time spent/bee/ flower(sec)	X±S.E	2.92±0.23	3.19±0.26	3.58±0.20	2.38±0.07	2.65±0.22	2.86±0.18	1.81±0.09	2.67±0.09	2.53±0.24
		C.V.	20.89	21.63	14.80	7.98	21.88	16.78	13.26	9.74	24.90
	(b)No.of flowers visited/bee/ minute	X±S.E	10.91±0.14	11.57±0.17	10.34±0.17	11.40±0.09	13.09±0.29	11.46±0.14	12.06±0.16	12.63±0.39	12.40±0.23
		C.V.	3.30	3.80	4.45	2.02	5.80	3.14	3.40	8.15	4.92

A.c = A. cerana; A.m = A. mellifera; A.d = A. dorsata.
X±S.E = Mean ± standard error about mean of 70 observations; C.V.= Coefficient of variation;
(a) At Pallimore and Hiranagar, *A.dorsata>A.mellifera>A.cerana* at 0900 hours ($P<0.01$) whereas, differences were insignificant at 1200 and 1500 hours ($P>0.05$).
(b) At Pallimore, *A. mellifera>A.cerana>A.dorsata* at 0900 and 1200 hrs ($P<0.05$); whereas, insignificant at 0900 hours ($P>0.05$); At Hiranagar, *A. mellifera>A.dorsata>A. cerana* at 1200 hours ($P<0.01$); whereas, insignificant at 0900 and 1500 hours ($P>0.05$).

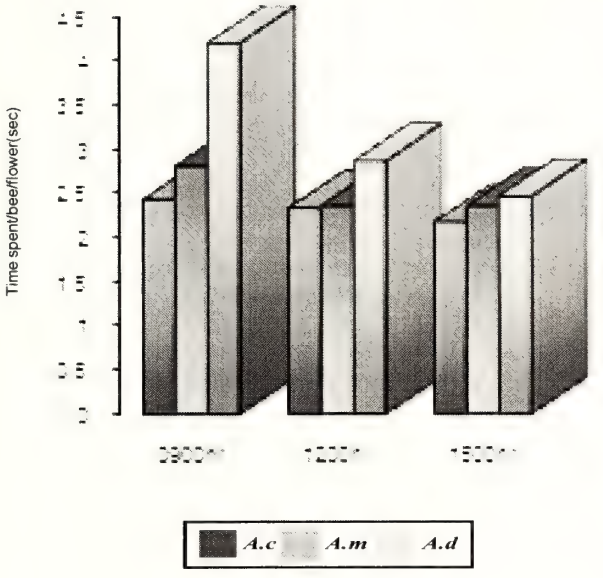

Fig.1: Variations in time spent/bee/flower(sec) by *Apis cerana, A.mellifera* and *A.dorsata* at different hours of the day on sarson crop at Pallimore, Kathua.

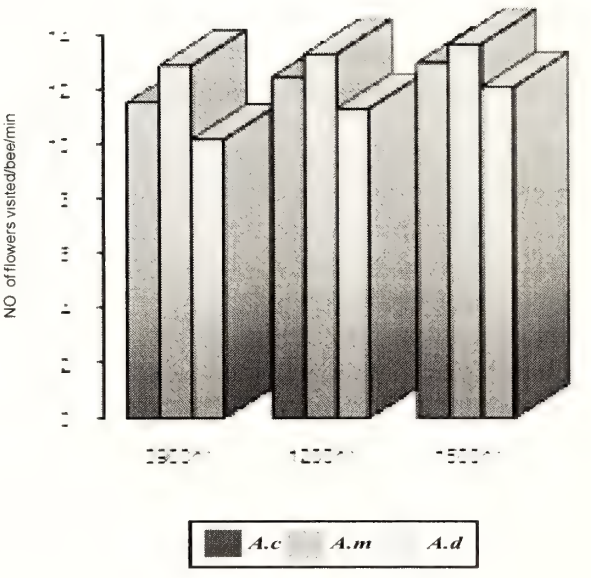

Fig.2: Variations in number of flowers visited/bee/min. by *Apis cerana, A.mellifera* and *A.dorsata* at different hours of the day on sarson crop at Pallimore,Kathua.

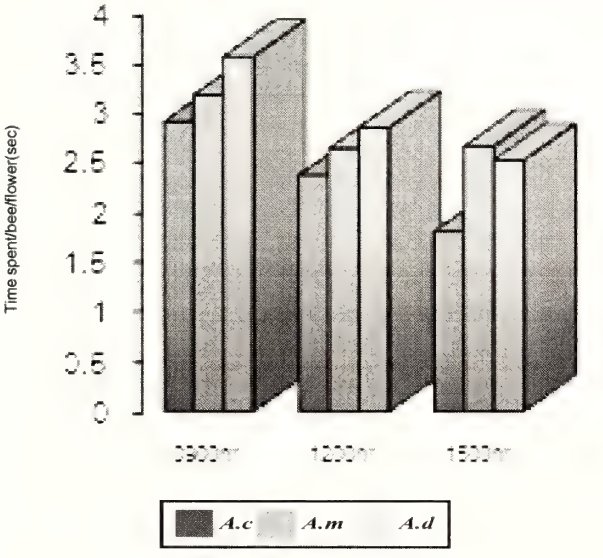

Fig.3: Variations in time spent/bee/flower(sec) by *Apis cerana, A.mellifera* and *A.dorsata* at different hours of the day on sarson crop at Hiranagar, Kathua.

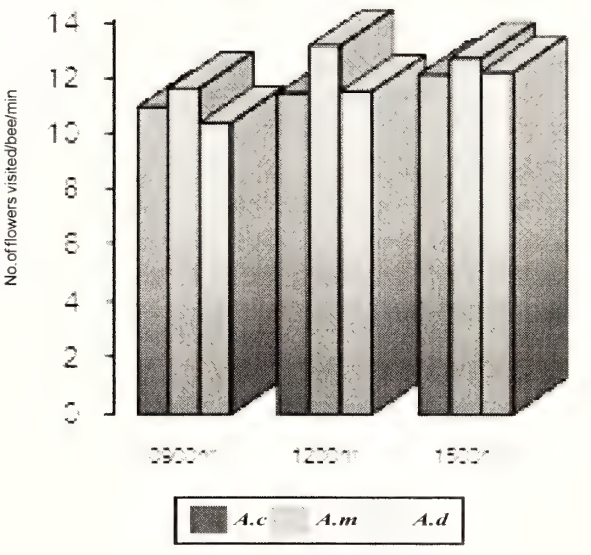

Fig.4: Variations in number of flowers visited/bee/min.by *Apis cerana, A.mellifera* and *A.dorsata* at different hours of the day on sarson crop at Hiranagar,Kathua.

visited by *A. cerana* and *A. mellifera* on mustard bloom. Murrell and Nash (1981) also reported that *A. cerana* spent less time per floret than *A. florea*, whereas *Apis dorsata* was intermediate in its foraging speed (mean 4.5 sec/floret). Time spent and number of flowers visited by *A. cerana indica* was reported as 4.61±0.13 sec/flower and 13.3 flowers/min by Adlakha & Dhaliwal (1979).

The variations in foraging rate and speed of *A. cerana, A. mellifera, A. dorsata* and *A. florea* may be due to different amounts of nectar and pollen present in various flowers as time spent per flower depends upon the amount of nectar present and morphology of flower (Pyke *et al.*, 1977).

Conclusion

It has been concluded that by placing both the colonies of bees (*A. cerana and A. mellifera*) and nesting of *A. dorsata* near by the fields of *Brassica campestris* increases the number of flowers visited per bee at a particular time, hence increases the pollination and enhances the yield.

Acknowledgements

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SEM structure of mandibular sensilla in the carpenter ant, *Camponotus compressus* (Fabricius) (Formicidae: Hymenoptera)

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Abstract

The moutparts in all polymorphic forms of carpenter ant, *Camponotus compressus* (Fabricius) (Hymenoptera: Formicidae) are adapted for grasping and feeding the prey. The mandibles are unsegmented, strongly sclerotized, large, shovel like, cuticular and powerful structures. The mandibles consist of dorsal sensilla trichoidea DT-I, DT -II and DT-III and on the ventral side VT-I, VT-II and the Sensilla basiconica VB in female and workers, while similar type of sensilla are found in male except sensilla basiconica. Each mandible consists of four incisor and three molar teeth in female and workers while only two incisor teeth are present in male.

Keywords: *Camponotus compressus, SEM, Mandible, Sensilla.*

Introduction

In most of the ant species, the mouthparts are adapted for grasping and feeding the prey (Snodgrass, 1935; Dumpert, 1972; Richard and Davies, 1987; Chapman, 1982,1998). Paul *et al.* (2002) reported that the receptors of taste are situated in the lower pair of jaws in the ants which distinguish different flavors of sweets and aromatic liquids. Galewski (1971) reported small peg-like sensilla on the dorsal surface of mandible in water beetle, *Dytiscus arew.* Mayhe-Nunes and Lanziotti (1995, 2002) reported the presence of seven teeth in female and workers while only two in male on the mandibles of ant, *Mycetarotes carinatus* suggesting sexual dimorphism. In the adult ants the mouth parts are equipped with mechano and chemoreceptors (Gotwald, 1969; Wheeler and Wheeler, 1970; Paul, 2001; Paul *et al.*, 2002).The present work therefore,has been undertaken to explore the surface ultrastruture of mandibles and different types of sensillae present on it in all polymorphic form of the carpenter ant, *Componotus compressus.*

Materials and Methods

The carpenter ant, *Camponotus compressus* colony was excavated from the semidried soil and the mandibles were removed carefully from polymorphs and fixed in 70% alcohol for 12 hours. The dehydrated mandibles were transferred to cold acetone, dried at room temperature, mounted on the carbon coated metallic stubs at different angles and proceeded for platinum coating in the Poloron gold coating automatic unit separately. Finally, the manibles were scanned under Jeol (JSM 6380 A) scanning electron microscope (SEM) at desirable magnification at the Instrumentation Centre of Vishveshvaraya National Institute of Technology (VNIT) Nagpur, India.

Results

In the carpenter ant, *Camponotus compressus* the mandibles are unsegmented, strongly sclerotized, large and shovel like cuticular mouth parts bearing strong basal three molar and

four distal incisor teeth in the female and workers while there are only two incisors in the male (Fig. 1,4). They differ in size among queen, male and workers (Table 1). They are indeed larger in worker, medium sized in female and small in male ants.

1. Sensilla in the Female Ants

On the dorsal as well as ventral surface of mandibles of female, two types of sensilla are observed viz., trichoid and basiconic sensilla. Trichoid sensilla (ST) are classified into five types as the dorsal sensilla trichoidea DT- I, DT- II, DT- III and ventral sensilla trichoidea VT- I, VT- II while the basiconic sensilla (VB) are located on the ventral side only.

In female the dorsal surface of dentition bears sensilla trichoidea (DT-I) (Fig. 1,2) while sensilla DT-II are long arising from a broad base and narrow towards the tip. The sensilla DT-III are short, pointed and curved towards the tip. The DT-I and DT-II scattered through out the dorsal surface (Table 2).

All over the ventral surface of mandibles, two types of trichoid sensilla are observed the VT-I and VT-II towards the dentition. The VT-I are long, slightly curved with pointed end. The VT-II sensilla are also long and pointed towards the tip lying on the marginal ventral surface. The postero ventral surface shows the basiconic type of sensilla, VB. The basiconic type of sensilla project from a slightly raised bulbous circular base and bears a pointed curved terminal end (Table 2).

2. Sensilla in the Male Ants

The dorsal surface of mandibles shows trichoid type of sensilla (Table 2) differentiated into three dorsal trichoid sensilla DT-I, DT-II and DT-III. The DT- I are lying on anterodistal margin of dentition while DT-II and DT-III are scattered throughout the dorsal surface of the mandibles (Table 2).

Similarly, the ventral surface of mandibles shows trichoid sensilla differentiated into VT- I and VT- II types and are located towards the marginal ventral surface similar to that of female except in size (Fig. 3,4). The basiconic sensilla are totally lacking (Table 2).

3. Sensilla in the Worker Ants

On the dorsal and ventral surfaces of mandibles, the trichoid and basiconic sensilla are observed. The trichoid sensilla on the dorsal surface are differentiated into DT-I, DT-II and DT-III and on the ventral surface into VT-I and VT-II types (Table 2). The sensilla DT-I are present on marginal area of the dorsal region of mandibles. The sensilla DT-II are long, slightly curved, pointed and DT-III are short, scattered throughout the dorsal surface (Fig. 5,6).

The ventral surface of mandibles shows trichoid sensilla differentiated into VT-I and VT-II types on the anteroventral margin and the basiconic sensilla (VB) on the posteroventral surface. The morphology of sensilla is similar to that of female except for difference in size (Table 2).

Discussion

In the carpenter ant, *Camponotus compressus,* the mandibles are large and powerful tools for prey catching, fighting, digging, seed crushing, wood-scraping, grooming, brood care and trophallaxis (Hölldobler and Wilson, 1990; Gronenberg *et al.,* 1998; Paul, 2001). In the *Camponotus compressus*, the mandibles are similar in structure to that in the ant *Mycetarotes carinatus* (Mayhé-Nunes and Lanziotti, 1995; 2002). In *Camponotus compressus*, dorsal side of mandibles possesses trichoid sensilla, DT- I, DT- II and DT- III which are densely distributed while VT-I and VT-II predominate ventral side and the sensilla basiconica, VB are found only in female and worker mandibles. The trichoid sensilla and small peglike sensilla basiconica, on the dorsal and ventral surface of mandibles in Dragon fly were reported as the mechanoreceptors and chemoreceptors respectively (Corbiere Tichane, 1971; Petryszak, 1977; Zacharuk, 1980; Kapoor, 1989; Wazalwar and Tembhare, 1999). The similar type of sensilla basiconica are also present on the mandible of carpenter ants, *Camponotus compressus.* The presence of seven teeth, four incisors and three molars in female and workers while two incisor teeth in male carpenter ants, *Camponotus compressus* suggest the species specific modifications of the mandibles in accordance with feeding habit and sexual dimorphism as found in ant, *Mycetarotes carinatus* (Mayhé Nunes and Lanziotti, 1995, 2002).

Table-1: Morphological observation on mandibles of adult polymorphic forms of *Camponotus compressus*

S. No.	Caste	Total length (mm)	Width (mm)	
			Anterior region	Posterior region
1.	Female	1.315 ± 0.086	0.7 ± 0.0056	0.5 ± 0.004
2.	Male	0.405 ± 0.0076	0.172 ± 0.003	0.0778 ± 0.006
3.	Worker	1.925 ± 0.071	1.016 ± 0.008	0.889 ± 0.021

Table-2: Morphological observations on the sensilla of mandibles of adult polymorphic forms of *Camponotus compressus*

S.No.	Caste	Dorsal region	Length (µm)	Width (µm)	Ventral region	Length (µm)	Width (µm)
1.	Female	Sensilla Trichoidea DT-I	133.34± 24.5	8.57± 5.43	Sensilla Trichoidea VT-I	243.48± 25.43	8.69± 2.15
		Sensilla Trichoidea DT-II	83.34± 14.5	8.35± 1.56	Sensilla Trichoidea VT-II	60.86± 12.4	4.76± 0.84
		Sensilla Trichoidea DT-III	41.67± 8.2	4.082± 0.56	Sensilla Basiconica VB	10.42± 1.56	0.361± 0.051
2.	Male	Sensilla Trichoidea DT-I	77.78± 11.54	2.89± 0.032	Sensilla Trichoidea VT-I	226.08 ± 23.54	3.78± 0.65
		Sensilla Trichoidea DT-II	44.45± 5.41	1.86± 0.045	Sensilla Trichoidea VT-II	16.67± 3.87	0.971± 0.015
		Sensilla Trichoidea DT-III	19.45± 2.65	1.11± 0.22			
3.	Worker	Sensilla Trichoidea DT-I	296.13± 25.5	20.1 ± 4.32	Sensilla Trichoidea VT-I	367.82± 45.3	16.41± 2.75
		Sensilla Trichoidea DT-II	123.4± 18.4	10.20 ± 1.82	Sensilla Trichoidea VT-II	137.94± 15.31	11.49 ± 2.82
		Sensilla Trichoidea DT-III	74.07± 15.2	6.75± 0.95	Sensilla Basiconica VB	13.31± 2.76	0.39± 0.035

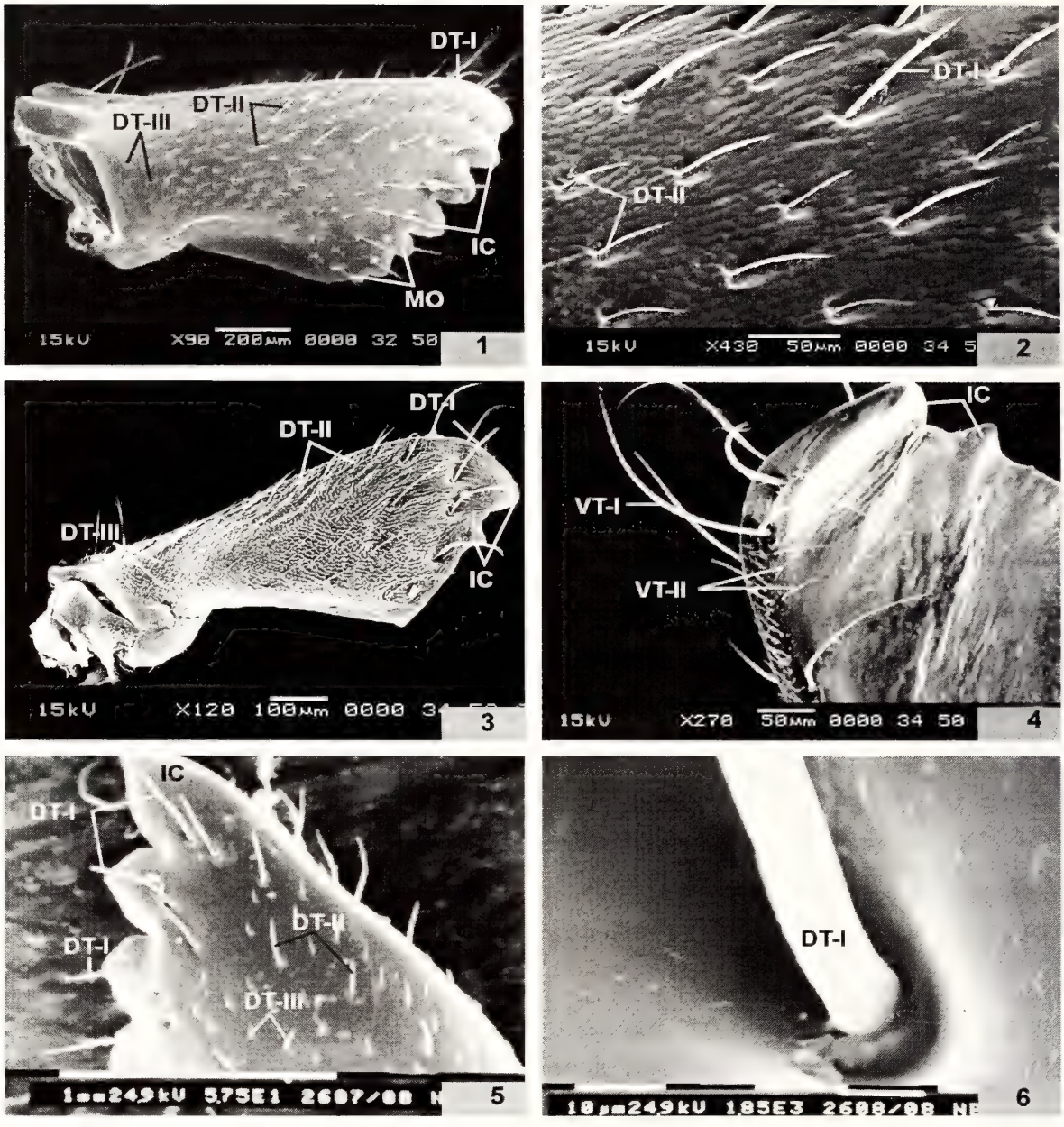

Figure: 1 SEM photomicrograph of dorsal surface of mandible showing four incisors (IC) and three molars (MO) teeth types of sensilla trichoidea DT-I, DT-II and DT-III in female.

Figure: 2 Magnified view of fig. 1 showing sensilla DT-I and DT-II on middorsal region in female.

Figure: 3 SEM photomicrograph of dorsal surface of mandible showing two IC and three types of sensilla DT-I, DT-II and DT-IIIon middorsal region in male.

Figure: 4 SEM photomicrograph of ventral surface of mandible showing sensilla trichoidea VT-I and VT–II in male.

Figure: 5 SEM photomicrograph of dorsal surface of mandible showing IC and DT-I, DT-II and DT-III in worker.

Figure: 6 Magnified views of fig. 5 showing sensilla DT-I arise from circular basal ring in worker.

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A contribution towards the insect fauna of Vadodara, Gujarat (India): The Order Hemiptera

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Abstract

Present study was undertaken to assess the diversity of the Order Hemiptera as well as its extent of changes in species composition from one habitat to another. Both agricultural fields and urban ecosystems were studied as there are 62 gardens and agricultural fields all around Vadodara. The results show that this city sustains a good diversity of 58 species, 51 genera and 22 families of hemipterans. Agricultural fields and urban areas had higher abundance and diversity of the families viz, Pentatomidae, Coriedae, Reduviidae and Aphididae, whereas families Lophopidae, Cicadidae, Dinidoridae and Acanthosomatidae were less in number. Turnover diversity along habitats was found to be same.

Keywords: *Pentatomidae, Agro and urban ecosystem, Species diversity, Percentage population.*

Introduction

According to recent estimate about 80,000 Hemipteran species are present worldwide. In India 77 families having 6500 species are found. Out of these, 2421 species are endemic to India (Alfred, 2003). Over 200 species belonging to 14 families are aquatic and semi aquatic, while remaining are terrestrial consisting of 6,300 species from 63 families (Ghosh, 1998). Keeping in view the importance of this group comprehensive survey was made on Hemipterans of Vadodara District (eastern part of the state of Gujarat in western India, located at 22°11' N latitude and 73°07' E longitude). The present study was undertaken with the purpose; to record the biodiversity of the Order Hemiptera in and around Vadodara, to find the extent of species composition changes in different habitats and to record the food plants of these insects and their conservation for the sustainability of these insects.

Materials and Methods

Survey sites were chosen based on accessibility and location within an eco region. Four different types of habitats were selected on the basis of ecological factors, flora, type of soil, surrounding environment and anthropogenic activities, to get an insight of the best possible insect diversity. Study was conducted during the period from 2005 to 2007.

a) Study sites

1. Agricultural fields: all around Vadodara (AF).
2. Community gardens: Sayaji Baug and Lal Baug (CG).
3. Fragmented habitat: University campus and Laxmivilas Palace compound (FH).
4. Residential areas: New and old city area (RA).

b) Collection method

Insects were collected throughout the year. Each study area was visited twice every month (7 am to 9 am and 5 pm to 7 pm) on the same day. At all the sites excepting agriculture fields, quadrats of 10m x10m were laid, while quadrats of 10m x 5m were laid in agricultural fields to decrease the sampling error. In Sweep net method each quadrat was covered/swept several times. Every sweep

was repeated after a gap of 10 minutes and 10 sweeps were performed each time. Hand collection was also carried in grass, shrubs, flowers, leaf litter, bare ground, tree bases, under stones, in field margins and tree trunks.

c) Identification

Insects collected were identified using keys available in Richard and Davies (1997), Borror *et al.* (1992), Leffroy (1909) and Ananthkrishnan and David (2004) and standard manuals. The identified material was confirmed from Entomology Division of Indian Agriculture Research Institute (IARI), PUSA , New Delhi.

d) Data analysis

The raw data of all the sampled sites from the field diaries of three consecutive years was transferred on to an electronic format in spreadsheet layout (Microsoft excel). The data was finally analyzed to calculate important value indices from all the sampling sites. The diversity indices were calculated by Species diversity and richness version 2.65 (Handerson, 2003). The richness of species within habitats was calculated using Shannon Weiner index (H) of alpha diversity index (H=" $P_i \log_e P$). For measuring extent of change in species, from one habitat to another Whitaker's, and Wilson's index were calculated:-

Whittaker index $\hat{a}_w = S/á - 1$

Wilson index $\hat{a}_T = g (H) + I(H)/2 á$

Results and Discussion

(Pertaining to Tables 1, 2, 3, 4 and Figure 1)

Insects recorded during present study belong to 22 families, 51 genera and 58 species. Out of these 7 families, 11 genera and 13 species belong to Homoptera while 15 families, 40 genera and 45 species belong to Heteroptera. It has been found that in Hemiptera, family Pentatomidae was maximum (17%), followed by Coriedae (15%), Reduviidae (10%), Aphididae (8%), Lygaeidae (7%) and the remaining 17 families were less abundant with the percentage of 2 to 5. Pentatomid bugs like *Halys dentatus, Eusarcocoris montivagus, Nezara graminea, Piezodorus rubrofasciatus, Plautia fimbriata, Eucanthecona furcellata* were found in all the habitats, due to availability of their food plants viz., *Morus alba* (white mulberry), *Trifolium species* (Clovers), *Casuarina equsetifolia* and graminaceous plants. *Eysarcocoris montivagous* was found on *Morus alba*, mimics the face of human beings; *Halys dentatus* camouflages with the trunk of trees like *Casuarina, Mangifera indica* (Mango), *Moringa oleifera* (Drumsticks) etc. to escape from predators like sparrows, crows, woodpeckers, drongo etc. Insects like cicada, white flies, negro bugs were found in and around agricultural fields. Overall percentage composition of such insects has been found to be less. Fragmented habitat represented the maximum species richness (57 species) followed by community gardens (53), agricultural fields (52) and minimum in residential areas (46) (Table 3). Value of Shannon Weiner index was less (3.85) for fragmented habitat as compared to that of Community gardens (3.86). Evenness index value of fragmented habitats is also less (0.94) as compared to gardens (0.95). Berger Parker dominance index for community gardens is minimum (0.03) showing that all the species in community gardens were evenly distributed. The Whittaker's and Wilson index (Beta diversity) of all the selected sites is almost identical, suggesting that the species turnover in Vadodara is same in different habitats.

The results of this study point towards the threat to biodiversity due to growing anthropogenic activities. Species diversity and richness varied all along the four study sites. It was found that fragmented habitats could support maximum number of bug species presumably due to heterogeneity of habitat as well as a wide range of hosts (vegetation). Residential areas of city were found to sustain a least number of species, due to lack of vegetation cover and intense anthropogenic activities. Main food plants of Hemipterans in agriculture fields are wheat, paddy, sugarcane, pigeon pea, gram etc., though vegetables of family Cucurbitaceae and Solanaceae are preferred.

During the 3 year study period, pest species (aphids, tree and leaf hoppers, white flies, red cotton bugs, leaf footed bugs etc.) in agricultural fields were found to increase every year. The

increase in pest population could be attributed to excessive use of Dimethoate and Carbofuran to control aphids and jassids; Fenvelarate and Deltamethrin for *Helicoverpa armigera* and *Spodoptera litura* in the agricultural fields of Vadodara rendering the pests resistant to pesticides. An immediate plan to advocate selective use of pesticides and looking for alternative pest control methods must be employed at the earliest.

Decline in the number of species of Belostomatidae, has also been recorded. *Belostoma indica* and *Sphaerodema annulatum,* the two aquatic bugs, predaceous on frogs and snails in the water bodies are decreasing in numbers. With heavy discharge from industrial and domestic sector plus constant spilling of polluted water from chemical factories into river Vishwamitri, deteriorates its water quality, causing death of frogs and snails. Ohba and Nakasuji, (2006) in Japan suggested that the conservation of frog populations is very important for the preservation of *Lethocerus deyrollei*, and for the maintenance of biodiversity within rice field ecosystems, frogs and other aquatic animals are major foods of these giant water bugs. Therefore, shrinkage of wetland Hemiptera should be prevented by treating industrial effluents properly instead of draining them into river. Habitat destruction due to urbanization and conversion of forest land into agricultural fields should be restricted to prevent the biodiversity loss.

Table- 1: Total No. of Families, Genera and Species.

Suborder	S. No.	Families	No.of genus	No.of species
Homoptera	1	Fulgoridae	1	1
	2	Lophopidae	1	1
	3	Cicadidae	1	1
	4	Membracidae	2	2
	5	Cicadellidae	2	2
	6	Aleyrodidae	1	1
	7	Aphididae	3	5
Heteroptera	8	Reduviidae	6	6
	9	Cimicidae	1	1
	10	Lygaeidae	3	4
	11	Pyrrhocoridae	2	2
	12	Coreidae	7	9
	13	Plataspididae	1	3
	14	Cydnidae	1	1
	15	Scutelleridae	2	2
	16	Acanthosomatidae	1	1
	17	Pentatomidae	10	10
	18	Dinidoridae	1	1
	19	Hydrometridae	1	1
	20	Gerridae	1	1
	21	Belostomatidae	2	2
	22	Nepidae	1	1

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Table-2: Checklist of Hemiptera within different habitats of Vadodara.

Family	Species	CG	AF	FH	RA
Cicadidae	*Platypleura octoguttata* Fabricius, 1798	-	+	+	-
Membracidae	*Oxyrachis tarandus* Fabricius 1798	+	+	+	+
	Leptocentrus taurus Fabricius 1803	+	+	+	+
Cicadellidae	*Idioscopus* neviosparsus Linnaeus	+	+	+	+
	Nephotettix nigropictus Stal 1870	+	+	+	+
Aphididae	*Aphis gossypie* Glover	+	+	+	+
	Aphis crassivora Koch 1854	+	+	+	+
	Aphis(Rhopalosiphus) maides Fitcher	+	+	+	+
	Aphis nerii Boyer de Fonscolombe 1841	+	+	+	+
	Myzus persicae Sulzer1776	+	+	+	+
Aleyrodidae	*Bemisia tabaci* Gennadius	+	+	+	+
Fulgoridae	*Pyrilla perpusilla* Walker	+	+	+	+
Lophopidae	*Kalidasa albiflos* Walker	+	+	+	+
Reduviidae	*Harpactor costalis* Sal	+	+	+	+
	Melenolestis picipes Herrich Shaffer,1848	+	+	+	+
	Acanthaspis siva Distant 1904	_	+	+	_
	Conorhinus species	_	+	+	_
	Prostemma flavomaculatum Leth	+	+	+	+
	Onchocephalus annulipes Stål, 1855	+	+	+	+
Cimicidae	*Cimex lectularius* Linnaeus, 1758	_	_	_	+
Lygaedae	*Blissus gibbus* Fabricius	+	+	+	-
	Lygaeus militaris Fabricius	+	+	+	+
	Lygaeus hospes Fabricius, 1794	+	+	+	+
	Dieuches uniguttatus Thunberg	+	+	+	+
Pyrrhocoridae	*Dysdercus cingulatus* Fabricius,1775	+	+	+	+
	Antilochus coqueberti Fabricius, 1803	+	+	+	+
Coriedae	*Riptortus linearis* Fabricius, 1775	+	+	+	+
	Cletus bipunctatus Westw	+	+	+	+

Table-2: Continued

	Cletomorpha raja Distant, 1892	+	+	+	+
	Anoplocnemis phasianus Fabricius, 1781	+	+	+	+
	Homoeocerus variabilis Dallas, 1852	+	+	+	+
	Homoeocerus prominulus Fabricius	+	+	+	+
	Clavigralla gibbosa Spin	+	+	+	+
	Petillia calcar Dallas, 1852	+	+	+	+
	Petillia lobipes Westwood, 1842	+	+	+	+
Dinidoridae	*Aspongopus janus* Fabricius, 1775	+	+	+	_
Acanthosomatidae	*Elasmostethus recurvum* Dallas	+	+	+	+
Scutelleridae	*Chrysocoris stolli* Wolff, 1801	+	+	+	+
	Scutellera nobilis Fabricius, 1775	+	+	+	+
Plataspididae	*Coptosoma cribrarium* Fabricius, 1798	+	+	+	+
	Coptosoma testacea Walker, 1867	+	+	+	+
	Coptosoma siamicum Walker	+	+	+	+
Pentatomidae	*Eysarcocoris montivagus* Distant,	+	+	+	+
	Nezara graminea Fabricius, 1787	+	+	+	+
	Piezodorus rubrofasciatus Fabricius, 1787	+	+	+	+
	Halys dentatus Fabricius, 1775	+	+	+	+
	Podisus maculiventris Say, 1832	+	+	+	+
	Placosternum Taurus Fabricius, 1781	+	+	+	+
	Hylomorpha picus Fabricius, 1794	+	+	+	+
	Bagrada picta Fabricius, 1775	+	+	+	_
	Plautia fimbriata Fabricius, 1787	+	+	+	+
	Eucanthecona furcellata Wolff, 1801	+	+	+	+
Cydnidae	*Cydnus indicus* Westwood, 1837	+	+	+	+
Hydrometridae	*Hydromitra vittata* Stål, 1871	+	_	+	_
Gerridae	*Gerris Tristan* Kirkaldy	+	_	+	_
Belostomatidae	*Belostoma indicum* Lep.et serv	+	_	+	_
Nepidae	*Sphaerodema annulatum* Fabricius	+	_	+	_
	Laccotrephes maculates Fabricius	+	_	+	_

Table-3: Species diversity and evenness in all the study sites.

Diversity measure	Agricultural Fields	Community Gardens	Fragmented Habitats	Residential Sites
Species number	52	53	57	46
H	3.729	3.861	3.853	3.532
J	0.918	0.950	0.949	0.869
Berger-parker	0.052	0.034	0.046	0.061

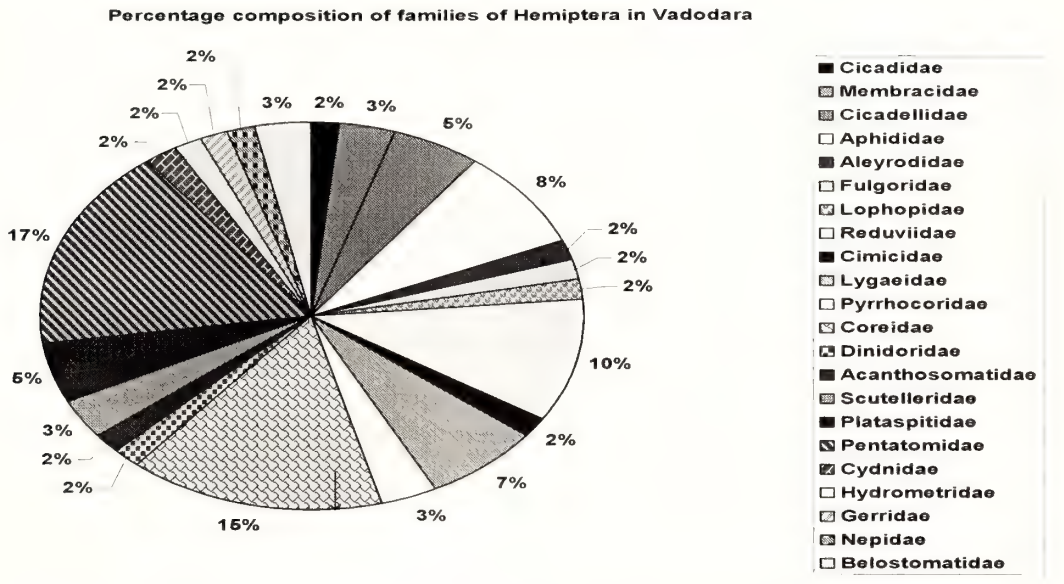

Fig.1: Overall percentage composition of Hemipteran families.

Table-4: Beta diversity index between all study sites.

Sites	Whitaker's and Wilson's index
AF-CG	0.083
FH-RA	0.127
FH-AF	0.045
RA-CG	0.090
RA-AF	0.081
FH-CG	0.036

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Natural parasitism of leaf miner, *Chromatomyia horticola* (Goureau) (Diptera: Agromyzidae) on vegetable crops in Kashmir (India)

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Abstract

The present paper reports the occurrence of 7 hymenopteran parasitoids of Agromyzid leaf miner, *Chromatomyia horticola* (Goureau) (Diptera: Agromyzidae) for the first time from Kashmir (India). The various parasitoids recorded are 5 eulophids (*Chrysocharis horticola* Mani, *Diglyphus horticola* Khan, *Diglyphus* sp., *Pediobius indicus* Khan and *Euderus agromyzae*) and 2 braconids (*Opius* sp. and *Dacnusa* sp.). *Dacnusa* sp. is also a new parasitoid record of *C. horticola* for India. Some field observation have been made on the seasonal occurrence, distribution and percentage of parasitoids of *C. horticola* recorded in various vegetable crop fields in different areas and regions of Kashmir.

Keywords: *Hymenoptera, Parasitoids, Chromatomyia horticola, Eulophidae, Kashmir.*

Introduction

Agromyzid leaf miner, *Chromatomyia horticola* (Goureau) (=*Phytomyza horticola*) is a pest of economic importance on several vegetables in both the temperate and tropical regions (Spencer, 1973). It is more common in the Mediterranean area and occurs widely throughout Asia (Gencer, 2005). The larvae of this species feed within the leaves of the host plant and this feeding can severely reduce yield and/or kill the plant at high fly density. In Kashmir Valley (India), *C. horticola* was earlier reported infesting some vegetable crops like, pea, kale, mustard, rape, turnip, radish and some ornamental flowering plants (Zaka-ur-rab, 1981 and Bhagat *et al.,* 1989). Many parasitoids are known to attack *C. horticola* in vegetable ecosystem in other parts of the world and some previous reports in this connection have been given by Mani (1971), Khan (1985), Chen *et al.* (2003) Gencer (2004 & 2005) and Purwar *et al.* (2003). However, no published record has been found on the parasitoid complex of *C. horticola* on vegetable ecosystem in Kashmir. Thus the objective of this study was to determine parasitoids of *C. horticola* occurring in Kashmir (India).

Materials and Methods

Field study was carried out during the year 2005-2006, in 5 districts of Kashmir Valley viz., Baramullua, Badgam, Ganderbal, Srinagar and Pulwama, selecting two sites from each district. The sites visited for sample collection were: Sumbal & Sopore (Baramulla); Bugam & Narkarah (Budgam); Nunar & Kangan (Ganderbal); Idgah & Danderkah (Srinagar) and Hispora & Pampore (Pulwama). The miner fly infested leaves of vegetable plants; *Brassica campestris*, *B. oleracea acephala*, *B. o. gongylodes*, *B. rapa*, *Pisum sativum*, *Alium cepa* and *Malva sylvestris* were collected. The sampling was repeated weekly from May to August, which is the period when the infestation of *C. horticola* occurs on vegetable crops in Kashmir (Zaka-ur-rab, 1981 and Bhagat *et al.,* 1989). In each sample, 100 infested leaves

were randomly collected from each study site. The leaf samples were brought to the laboratory and kept in plastic culture container/rearing jars, covered with muslin cloth, till the emergence of adult flies or their parasitoids. The laboratory temperature was maintained at about 25-30 ^{0}C with relative humidity of 60-70%. The emerged flies or parasitoids were collected from the containers and preserved in 70 % ethanol or as dry material. The identification of parasitoid specimens was carried by using work of Mani (1971), Hyat (1985), Khan (1985) and Wharton *et al.* (1997). Number of specimens for each species was counted and percentage of each parasitoid was estimated.

Results and Discussion

Frequent visits to vegetable growing areas were conducted over the 2 years period of the survey, providing ample opportunity to make general field observations. *C. horticola* was recorded infesting 7 vegetable crops viz., mustard (*Brassica campestris*), kale (*B. oleracea* var. *acephala*), knoll-khol (*B. o.* var. *gongylodes*), turnip (*B. rapa*), pea (*Pisum sativum*), onion (*Alium cepa*) and malva (*Malva sylvestris*). Among these crops, malva and onion are 2 new host crop records of *Chromatomyia horticola* for Kashmir (India). In 2005, the survey of these vegetable crop plants from May-August yielded 1004 adult specimens of *C. horticola*. Like wise in 2006, 999 adults of *Chromatomyia horticola* were recovered. Higher numbers of leaf miner adults emerged from leaves collected from *B. campestris* and *P. sativum*. During the two years of this investigation in the Valley, the infestations of *Chromatomyia horticola* were observed more serious during the month of May when limited control was exerted by parasitoids. As shown in table 1, the monthly mean number of *Chromatomyia horticola* recovered in the months of May was much higher than that of total parasitoids. Tsumou *et al.* (2008) have also reported *C. horticola* as a serious pest in slightly cooler season (May) in Japan.

Also the figures 1 & 2 show that the mean number of adult *Chromatomyia horticola* emerged during the months of June and July were less as compared to the total monthly mean number of parasitoids recovered. However, the monthly mean of *Chromatomyia horticola* in the months of May was much higher than that of total parasitoids.

During the course of this investigation, a total of 7 hymenopteran parasitoid species were recorded on the leaf miner, *C. hortcola*. These included 5 eulophids, *Chrysocharis horticola* Mani, *Diglyphus horticola* Khan, *Diglyphus* sp., *Pediobius indicus* Khan, *Euderus agromyzae* and two braconids, *Opius* sp. and *Dacnusa* sp. The parasitism of *C. horticola* by the afore mentioned parasitoids is the first report from Kashmir. *Dacnusa* sp. is also a new record of parasitoid of *C. horticola* for India. The summary of parasitoids of *Chromatomyia horticola* recovered from various vegetable crops is provided in table 1. As seen in table 1 & 2, a total of 645 parasitoids were recovered in 2005, out of which *D. horticola* and *Diglyphus* sp. together were 407 (230+177) forming 63.10 % (35.66 % + 27.44 %) of the total parasitoids. Likewise in 2006, a total of 607 parasitoids were recovered out of which, these two parasitoids together were 387 (225+162) forming 63.77% (37.06 %+ 26.68%) of the total parasitoid collection. So, *D. horticola* and *Diglyphus* sp. were recorded as the most common parasitoids of *C. horticola* in Kashmir (India) and hence considered to be the most important natural enemies of the *Chromatomyia horticola* in this region. Purwar *et al.* (2003) have also reported *D. horticola* as the dominant parasitoid of *C. horticola* on *P. sativum* in Himachal Pradesh (India).

As depicted from the table 2, *Opius* sp. and *Dacnusa* sp. were recorded to be the least common parasitoids of *C. horticola* in both the years of study in Kashmir. Also the table 1 and figures 1 & 2 show that the mean number of adult *Chromatomyia horticola* emerged during the months of June and July in both years, 2005 and 2006 were less as compared to the total monthly mean number parasitoids recovered. The parasitoids of *C. horticola* remained active in the field mostly from May to July but the highest activity of these parasitoids was witnessed during the month of June when most number of the parasitoids were recorded; 329 out of 645 (51%) in June 2005 and 305 out of 607 (50%) in June

2006. This study is in agreement with Tsumou *et al.* (2008) who have also witnessed the months of June and July as the period of highest activity of the parasitoids of *Chromatomyia horticola* on pea in Japan.

Table-1: Weekly No. of miner fly, *Chromatomyia horticola* and its Hymenopteran parasitoids recorded on vegetable crops during 2005-2006 survey in Kashmir (India)

Month/ week	No. of miner fly (*C. horticola*) emerged		No. of parastioids emerged by rearing of miner fly infested leaves																	
			Dacnusa sp.		*Opius* sp.		*D. horticola*		*Diglyphus* sp.		*Chrysocharis horticola*		*P. indicus*		*E. agromyzae*		*Total Parastioids*	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
May																		
I week	162	143	-	-	-	-	4	3	3	1	-	-	-	-	-	-	7	4
II week	135	125	5	2	1	-	12	17	10	6	2	-	-	2	1	-	31	27
III	191	170	6	2	5	4	21	36	15	19	6	8	3	4	-	2	56	75
IV	123	141	6	4	6	3	33	25	23	18	9	8	7	6	4	2	88	66
Mean	152.75	144.75	4.25	2	3	1.75	17.5	20.25	12.75	11	4.25	4	2.5	3	1.25	1	45.5	49.75
June																		
I	75	71	6	6	7	1	33	39	20	25	13	10	9	11	8	5	96	97
II	56	80	2	5	3	3	28	22	19	18	11	9	9	7	7	6	79	70
III	68	54	1	2	1	3	19	21	30	28	9	10	11	18	6	4	76	86
IV	40	44	-	3	1	1	23	17	13	12	10	7	8	6	3	5	58	52
Mean	59.75	62.25	2.25	4	3	2	25.75	24.75	23	20.75	10.75	9	9.25	10.5	6	5	77.25	76.25

Table-1: Continued

Month/ week	No. of miner fly (*C. horticola*) emerged		No. of parastioids emerged by rearing of miner fly infested leaves															
			Dacnusa sp.		*Opius* sp.		*D. horticola*		*Diglyphus* sp.		*Chrysocharis horticola*		*P. indicus*		*E. agromyzae*		*Total Parastioids*	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
July																		
I	36	39	-	2	-	-	13	18	17	15	12	9	4	7	5	6	51	55
II	25	34	-	-	-	-	15	18	12	11	9	11	3	4	5	3	44	47
III	28	32	-	-	-	-	11	9	9	10	8	6	2	-	1	2	30	27
IV	31	24	-	-	-	-	5	2	1	2	-	2	-	3	2	-	8	9
Mean	30	32.25	-	0.5	-	-	11	10	9.75	7.75	7.25	7	2.25	4.25	3.25	2.25	33.25	34.5
August																		
I	15	19	-	-	-	-	4	4	2	3	1	-	-	-	-	-	7	7
II	9	10	-	-	-	-	4	-	3	-	-	-	-	-	-	-	7	-
III	7	6	-	-		-	5	1	-	1	-	-	-	-	-	-	-	-
IV	3	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	8.5	10.5	-	-	-	-	3.25	1.25	1.25	1	0.25	-	-	-	-	-	3.5	1.75

Table-2: Percentage emergence of parasitoids from *Chromatomyia horticola* during 2005-2006 survey in Kashmir

Parasitoid species	Number of Individuals		% age of Parasitoids	
	2005	2006	2005	2006
***Opius* sp.**	24	15	3.72	2.47
***Dacnusa* sp.**	26	24	4.03	3.95
Diglyphus horticola	230	225	35.66	37.06
***Diglyphus* sp.**	177	162	27.44	26.69
Chrysocharis. horticola	90	80	13.95	13.18
Pediobius indicus	56	68	8.68	11.20
Euderus agromyzae	42	33	6.51	5.44
Total parasitoids	645	607		

Table-3: Host-Crop Complex of hymenopteran parasitoids of *Chromatomyia horticola* recorded during 2005-2006 survey in Kashmir (India)

Hymenopteran Parasitoid	Host Plants of *C. horticola*
Family 1. Braconidae	
Opius sp.	*B. campestris*
Dacnusa sp.	*B. campestris, P. sativum*
Family 2. Eulophidae	
Diglyphus horticola	*A. cepa, B. campestris, B. o. acephala, B. o. gongylodes, B. rapa, M. sylvestris, P. sativum*
Diglyphus sp.	*A. cepa, B. campestris, B. o. acephala, B. o. gongylodes, B. rapa, M. sylvestris, P. sativum*
Chrysocharis horticola	*A. cepa, B. o. Acephala, B. o. gongylodes, P. sativum*
Pediobius indicus Khan	*A. cepa, P. sativum, B. o. acephala*
Euderus agromyzae	*A. cepa, B. campestris, B. o. acephala, P. sativum*

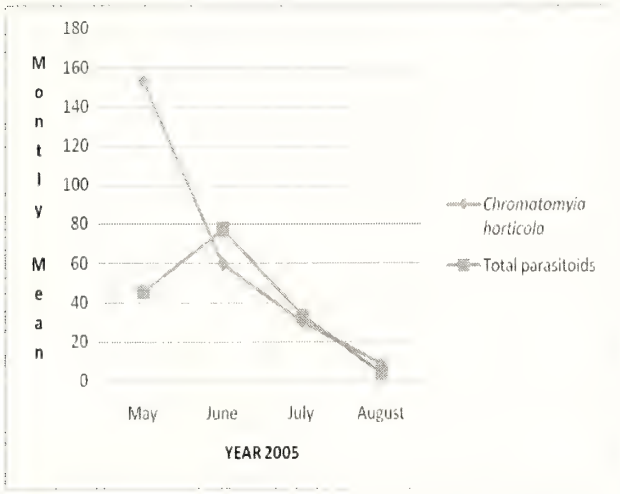

Fig. 1: Seasonal abundance of the leaf miner, *Chromatomyia horticola* and its parasitoids collected on various vegetable crops in Kashmir Valley from May to August 2005.

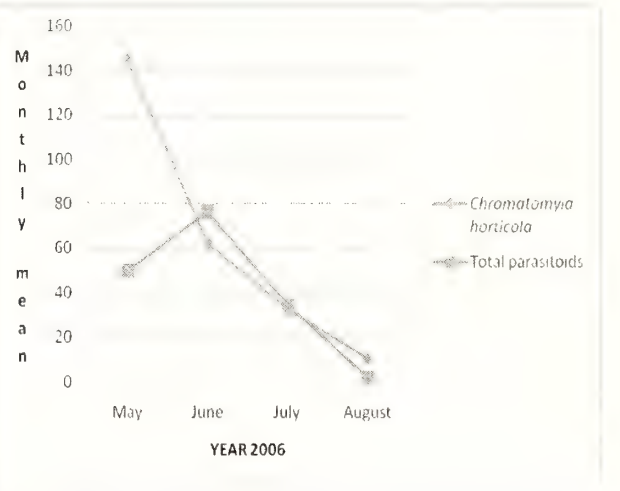

Fig. 2: Seasonal abundance of the leaf miner, *Chromatomyia horticola* and its parasitoids collected on various vegetable crops in Kashmir Valley from May to August 2006.

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Bioecology of Til Hawk Moth, *Acherontia styx* Westwood

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Abstract

The bioecology of til hawk moth, *Acherontia styx* Westwood was studied on *Sesamum indicum* (Linn.) variety TKG-22 under field and lab. condition during 2004-06. The eggs were globular in shape, yellow in colour with 0.70-0.95 mm in size. The incubation period of the eggs was 2-4 days with the neonate period of 10-15 minutes. There were five larval instars and length of the completely developed larva was 68-79 mm with larval period of 20-21 days. The maximum larvae were obtained during late August to September. The pre-pupal and pupal periods were 3-4 and 14-23 days respectively, with pupae conical in shape. The mating was always at morning (0.07-0.10 minutes) followed by oviposition (24 to 36 hours) with fecundity of 5-8. Life span of the adult was 3-5 days, total life cycle was completed in 39-52 days. Mean adult emergence (%), sex ratio and growth index were 95 to 100%, 1:1 and 2.64 to 2.27 respectively. There are only three generations in a year. The plants were infested to the extent of 31.6% by this insect. Maximum damage is caused during September-October.

Keywords: *Bioecology, Acherontia styx Westwood.*

Introduction

Sesame *Sesamum indicum* Linn. is the oldest indigenous oilseed crop of the world and also a major oilseed crop of India. This crop is attacked by 29 species of insect pests in different stages of its growth (Biswas *et al.,* 2001).

Til hawk moth, *Acherontia styx* Westwood is a sporadic pest but voracious feeder of sesame crop at larval stage. The larvae feed voraciously on leaves and defoliate the plants; and is capable of inflicting heavy damage at times. Only one larva is enough to denude the whole plant.

The present work is a novel approach in Bundelkhand Zone of Madhya Pradesh, which has not been studied before or explored elaborately. But, some work done on its bionomics has been reported by Mehta and Verma (1968), Lefroy (1990), Rai *et al.* (2001), Sharma and Choudhary (2005) and Atwal and Dhaliwal (2005). The present investigations conducted on different aspects of the bioecology of this insect are reported in this research paper.

Materials and Methods

Studies on the bionomics of til hawk moth, *Acherontia styx* Westwood were undertaken in the field in ambient conditions during July to December of 2004,2005 and 2006. For laboratory experiments, the cultivated sesame variety, TKG-22 and JT-7 were grown in glass jars. Full fed caterpillars were collected from the field of sesame crop and reared in glass jars and Petri dishes (7.5 cm diameter) on sesame leaves and fruiting bodies. The leaves/flowers were changed daily up to the second instar larval stage. Thereafter, buds, flowers, capsules and leaves were provided as food for the later larval stages. The matured larvae transform into pupae inside the bud and sometimes in deep dry soil available in fields, placed in glass jars/Petri dishes in the lab. Moths emerging from pupae were released in lantern globes containing cotton swabs dipped in 20% glucose solution. Sexes were examined by different morphological characters and moths were

kept under constant watch for studying mating, oviposition behaviour and egg laying.

Freshly laid eggs were counted and placed on fresh sesame leaves with the help of moist soft camel hairbrush. Observations were recorded on their colour, size, shape and incubation period. Duration of each larval instar, body segments and legs were recorded. Measurements of various stages were taken under the binocular with the help of ocular micrometer. However, advanced larval stages and pupae were measured with the help of Vernier callipers.

For adults, emerging from the above (the group being reared from freshly laid eggs), mating period, oviposition period, fecundity per female, pre pupal, pupal period of larvae and longevity of male and females were recorded.

Results and Discussion

The eggs (Fig.1a) are generally laid singly on the upper as well as lower surface of leaves. An adult female lives 3-5 days and lays only 3 to 8 eggs at different intervals, sometimes up to two days. Freshly laid eggs are greenish white in colour and measure 00.70 to 00.80 mm but they turn yellow during the incubation period when they grow to 00.90 to 00.95 mm (Table 3).

The incubation period varies from 02.00 to 04.00 days with subsequent hatching of eggs. The eggs are oval (1.2 x 1.5mm), shiny, smooth and pale green, changing to yellowish green just before hatching. Laid singly on the under and upper surface of leaves on peripheral twigs, usually hatching three to five days later (http:// www.styx.htm). The pale-yellow larvae emerge in 2-5 days reported by Rai *et al.* (2001); Sharma and Choudhary (2005); Atwal and Dhaliwal (2005). Year wise observation and the mean range is given in Table 3.

There are five larval instars in addition to the neonate larva, which is the newly hatched instar from the egg after completion of incubation. The neonate larva is a cylindrical white coloured instar with a conspicuous projection at the hind end of abdomen, referred as 'dunk'. This stage feeds on its own egg case in the beginning and after 10-15 minutes on the leaves. The nascent larva measures 03.50 to 04.00 mm x 00.35 to 00.50 mm whereas fully fed larva before moulting to the 1st instar grows to 04.50-05.00 mm x 00.60-00.70 mm. The dunk is white and measures 02.50-03.00 mm in full grown nascent larva, Table 3. After about 20 minutes the larva moults to 1st instar (Fig.1 b).

The first instar larva (Fig. 1c) is yellowish green in colour with black dunk and measures 09.00-12.00 x 01.00-01.50 mm. This larval instar persists for 115.00-130.00 hrs and when fully fed it measurers 18.00-22.00 x 02.00-02.40 mm with yellow green head and thorax; and dark green abdomen. Three pairs of thoracic legs on 1st-3rd thoracic segment and four pairs of prolegs on 6th-9th abdominal segments are observed. A fifth pair of prolegs is seen on the 13th abdominal segment. All legs are shiny brown in colour. The dunk, in this instar, is black and measures 02.90 to 03.00 mm. The larva feeds voraciously by scrapping on leaves but stops feeding some time before moulting to the next instar. Feeding and moulting period is shown in Table 2 and 3.

The second instar larva (Fig.1d) is also green in colour just as the first instar but the dunk changes to dark reddish black measuring 25.00-35.00 x 03.40-04.20 mm. This instar persists for 73.00-77.00 hrs and moults to the third instar. Before moulting, the fully fed larva measures 36.20-45.00 x 04.50-06.00 mm. The hook like dunk in this stage is dark reddish black and measures 05.50-06.00 mm long and has a width of 00.35-00.40 mm (Table 2 and 3). The legs develop minute black spots and this instar feeds on soft parts of branches in addition to leaves.

The third instar larva (Fig.1e) is quite big in size, 50.00-55.00 mm x 06.30-06.50 mm when newly moulted and 57.00-60.00 mm x 06.60-07.00 mm when fully fed. The dunk also grows accordingly and measures 06.50-07.00 mm x 00.45-00.50 mm (Table 3). The body colour is green with light yellow 'V' shaped marks on the abdomen and minute tubercles laterally on the terga. Thus this instar looks plump, decorated with a pleasant mixture of soft colours. It voraciously feeds on the leaves and branches and almost

entire plant is denuded within 24 hrs. (Fig.1o,p). It also feeds on pods. The third instar lasts for 74.40 to 77.30 hrs including the feeding (66.40 to 70.00 hrs) and moulting (06.40 to 07.30 hrs) periods (Table 5).

The fourth instar larva (Fig.1f) has the same body colour as the previous instar and measures 61.20-64.40 mm x 07.10-07.40 mm having a cylindrical shape. The dunk changes its colour to yellow and measures 08.00 mm x 00.52 to 00.60 mm in size (Table 2). The head looks like that of a grasshopper with blackish yellowgreen colour. One pair of spiracles is situated laterally on the thorax and seven pairs on abdomen (4th to 10th segments). The last pair of spiracles is seen on the 11th segment. There are seven sharply defined yellow oblique lateral stripes on segments 5 to 11, each stripe edged above with dark blue region, sharply defined at the common edge but diffuse dorsad. Dunk is canary yellow, true legs black, prolegs and claspers green and anal flap green edged with yellow. Spiracles are oval, yellowish white with a central black slit, the whole bordered with brownish-green. The fourth larval instar lasts for 44.40-48.00 hrs including the feeding period of 34.40-40.00 hrs and moulting period of 08.00-10.00 hrs (Table 5). The fully fed larva before moulting is of 65.00-73.00 mm x 07.60-8.00 mm size (Table 2). This instar is a voracious feeder of leaves and only one larva is enough to denude the whole plant.

The fifth instar larva (Fig.1g) is again a colourful plump cylindrical creature as the earlier stage and measures 74.20-75.50 x 08.20-08.70 mm. Full fed caterpillar measures 77.20-82.00 x 09.00-10.00 mm with dark yellow dunk of 08.00-08.50 x 00.70-00.80 mm. The 5th instar larval duration is 68.00-78.30 hrs including the feeding and pre pupation period (Table 3 and 5).

Mehta and Verma (1968); Lefroy (1990); Rai *et al.* (2001); Atwal and Dhaliwal (2005); and Sharma and Choudhary (2005) observed that the full grown caterpillar is bright green in colour with light oblique yellow strips on each side and a horn like process on hind end of the body, which measures about 90-100mm in length and 1cm in width, coinciding with the present study.

Cannibalism has been observed when the moth is reared in the laboratory and is quite frequent in the fifth instar, when more than one larva is reared in a Petri dish, one attacks the other (Fig.1h). The attack is made by the older larva. After some resistance the younger one is injured and fluid oozing out of the injured terga of thoracic region is sucked by the winner. Thereafter, the injured is completely consumed leaving only the head capsule along with the prothorax. Also, during moulting process, the exuviae are completely consumed by the moulted caterpillars.

The mean larval period varies from 19.75 to 19.99 days in field conditions. The larval period of first generations during 2004, 05, and 06 were 19.83±0.66, 19.99±0.51 and 19.75±0.19 days respectively (Table 4).

Larval period is usually long and may last two months or more reported by Mehta and Verma (1968); Lefroy (1990); Rai *et al,* (2001); Atwal and Dhaliwal (2005) but Sharma and Choudhary (2005) reported it to be of 14-21 days, which is in agreement with the present study.

Pre pupa (Fig.1i), full-grown last/fifth instar larva stops feeding and burrows in 04.00-6.00 cm deep funnel in soil with head forwards. It forms an oral cell for pupation, shrinks in size and curves to a semilunar shape. Then abdominal and thoracic legs are lost and finally the head capsule is casted out and a pre pupa is formed. It is conical, dark yellowish green coloured measuring 40.00-41.00 x 05.00-05.30 mm (Table 3). The pre pupal duration varied in the three years of study and is found to be 78.00, 86.00 and 79.30 hrs for 2004, 05, and 06 respectively (Table 5).

At the end of this period a conical, soft, shining blood red coloured pupa is formed with two black eyes on the anterior end, which is the head region (Fig. 6j,k). Abdomen is distinctly marked in 9 segments, the terminal segment ending into a spine like structure. Sexual dimorphism can be seen in the pupa by the presence of genital and anal pores in the 8th and 9th segments respectively in male and on 7th and 9th segments in the female. The pupal duration ranges from 14.00 to 23.00 days (Table 3). According to Lefroy (1990); Rai

al., (2001); Atwal and Dhaliwal (2005); Sharma and Choudhary (2005), the full grown larvae burrow about 15cm deep in the soil and form an oval cell for pupation. The pupal period lasts for 15-21days in summer, coinciding with the present study. Larval and pupal developmental period (A) is recorded to be 32.85-43.65 days (mean 38.12±1.89 days) (Table 3).

The Adult moths are large, robust thick set with a wing span of 34.90 to 39.90 mm. These moths are commonly known as hawk moth, sphinx moth or death's head moth based on structural and behavioral characteristics. Adult hawk moths are also, called "robbers of honey" because they rob honey from honeycomb. The moths are swift fliers and often make hawk like darts to a source of light at dusk. The forewing of moth is decorated with a mixture of dark mottled brown and grey patterns with dark or black wavy markings and a prominent yellow spot on each wing. The abdomen is yellow in colour, hind wings are yellow greyish with black marks and large vertical line. The pro thorax carries a characteristic whitish and reddish brown mark, which appears like a human skull.

A pair of large, black and transparent eyes and a pair of spring like thin antennae are present on the lateral sides of head of both sexes. Male adults measure 30.00 to 30.02 mm (mean 30.00±0.0047 mm) in length and 34.00 to 35.02 mm (mean 34.90±0.21 mm) in width with an expanded wing (both wing span about 7 cm). Females are longer, being 37.05 to 38.00 mm (mean 37.72±0.24 mm) in length and 39.00 to 40.02 mm (mean 39.90±0.21 mm) in width with an expanded wing (both wing span about 8 cm) (Table 3). Males are smaller than the females. The sexes are identified by the presence of shiny greyish tuft on thorax with one pair of black dots in males. Females are larger in width and have shining reddish grey tuft like a human skull on the thorax (Fig.1m,n). Mehta and Verma (1968); Atwal and Dhaliwal (2005); Sharma and Choudhary (2005) have also recorded similar features in adults.

The adult emergence (B) percentage was 95 to 100, 98 to 100 and 92 to 100 (mean range 95 to 100 ± 0.87 percent) during the 3 consecutive years of study respectively. Moths emerged from pupae during night with male and female sex ratio of 1:1.

Male and female moths after emergence, rest for a while on branches and soil and then undertake short flights in search of food. Next night again, the male moths undertake flight, first in search of food for 2.00-4.00 hrs and then engage in characteristic high speed directed flights in search of pheromone plumes. During this time females are inactive, releasing pheromones only. Pre mating period has been recorded as 21.00 to 24.00 hrs (mean 22.70±1.13 hrs). The mating is complete within 00.07 to 00.10 minutes (mean 0.087±0.0057 minutes) as shown in Table 3.

After mating, the pre oviposition period is 11.00 to 15.00 hrs (mean 12.45±1.53 hrs). Oviposition period (egg laying time) ranges between 24.00 to 36.00 hrs (mean 27.60±4.73 hrs.) with post oviposition period of 01.50 to 03.00 days (mean 02.12±0.46 days). During oviposition period the female moth lays eggs singly on the leaves. Eggs are laid in early mornings only. Fecundity per females has been found to be 05.00 to 08.00 eggs (mean 06.49±0.72) during all three seasons of study (Table 3).

Longevity of males and females ranged from 02.00 to 03.00 days (mean 02.56±0.16 days) and 03.00 to 05.00 days (mean 3.76±0.39 days) respectively (Table 3).

Growth index (B/A) was found to be 02.79 to 02.38, 02.27 to 02.65 and 02.49 to 02.17 in three consecutive years respectively (Mean range 02.27 to 02.64±0.078).

Total Life span of adult from egg laying to adult stage was completed in 38.92 to 39.14 days during all three seasons of study (Table 4). One generation was completed during August to October each year of study. Similar, results were reported by Mehta and Verma (1968); Atwal and Dhaliwal (2005); and Sharma and Choudhary (2005).

Nature and extent of damage: Maximum percent damage to flowers caused by larvae of *Acherontia* was 31.6% during late September (38th standard meteorological week) and minimum (3.8%) at begining of September (34 S.M.W.) (Fig. 2).

The percent damage of flower is positively correlated with the maximum temperature but negatively correlated with the minimum temperature, relative humidity and rainfall (Table1).

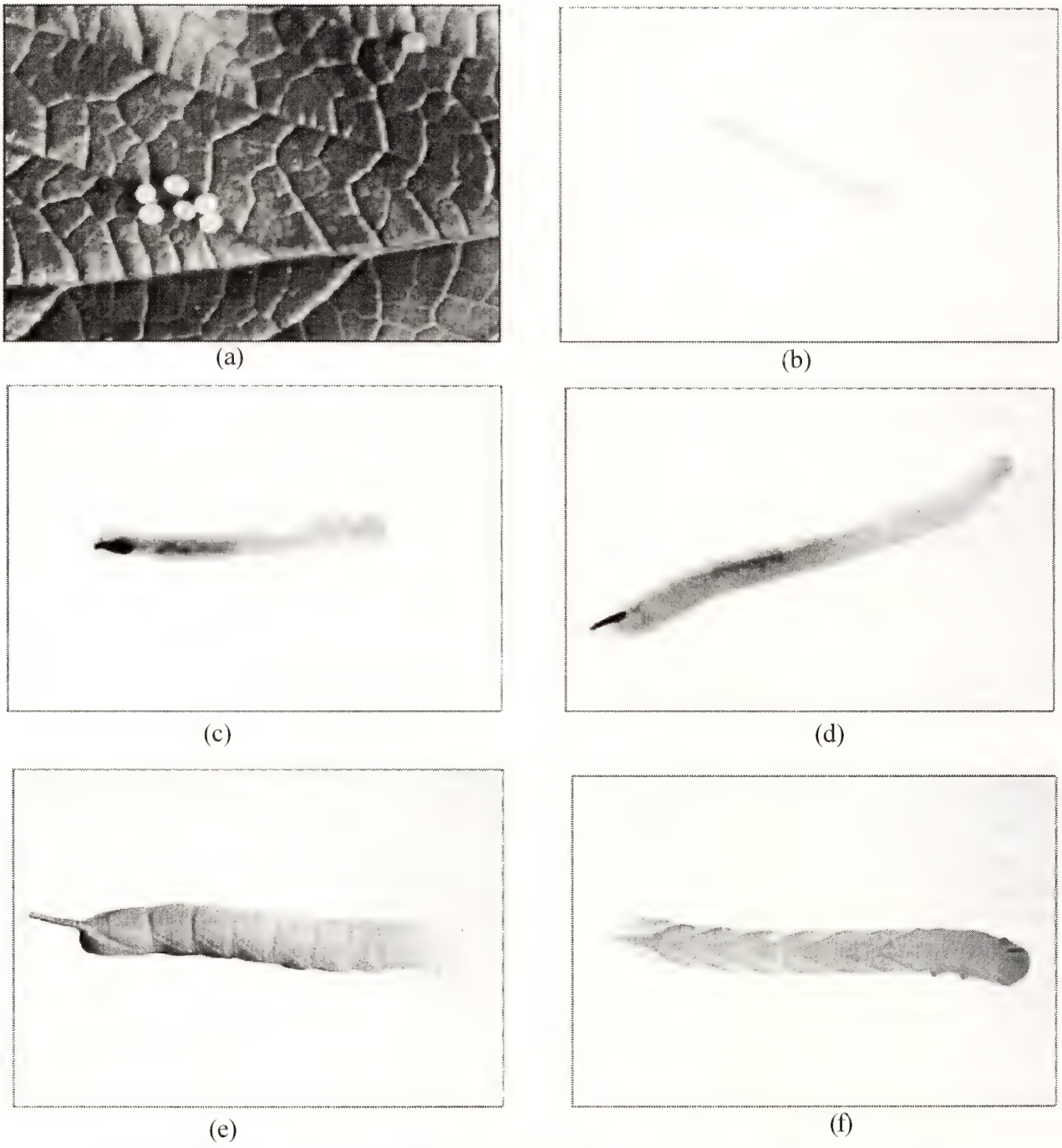


Fig. 1: (a) Eggs of *Acherontia styx* Westwood (b) Neonate larva (c) First instar larva (d) Second instar larva (e) Third instar larva (f) Fourth instar larva

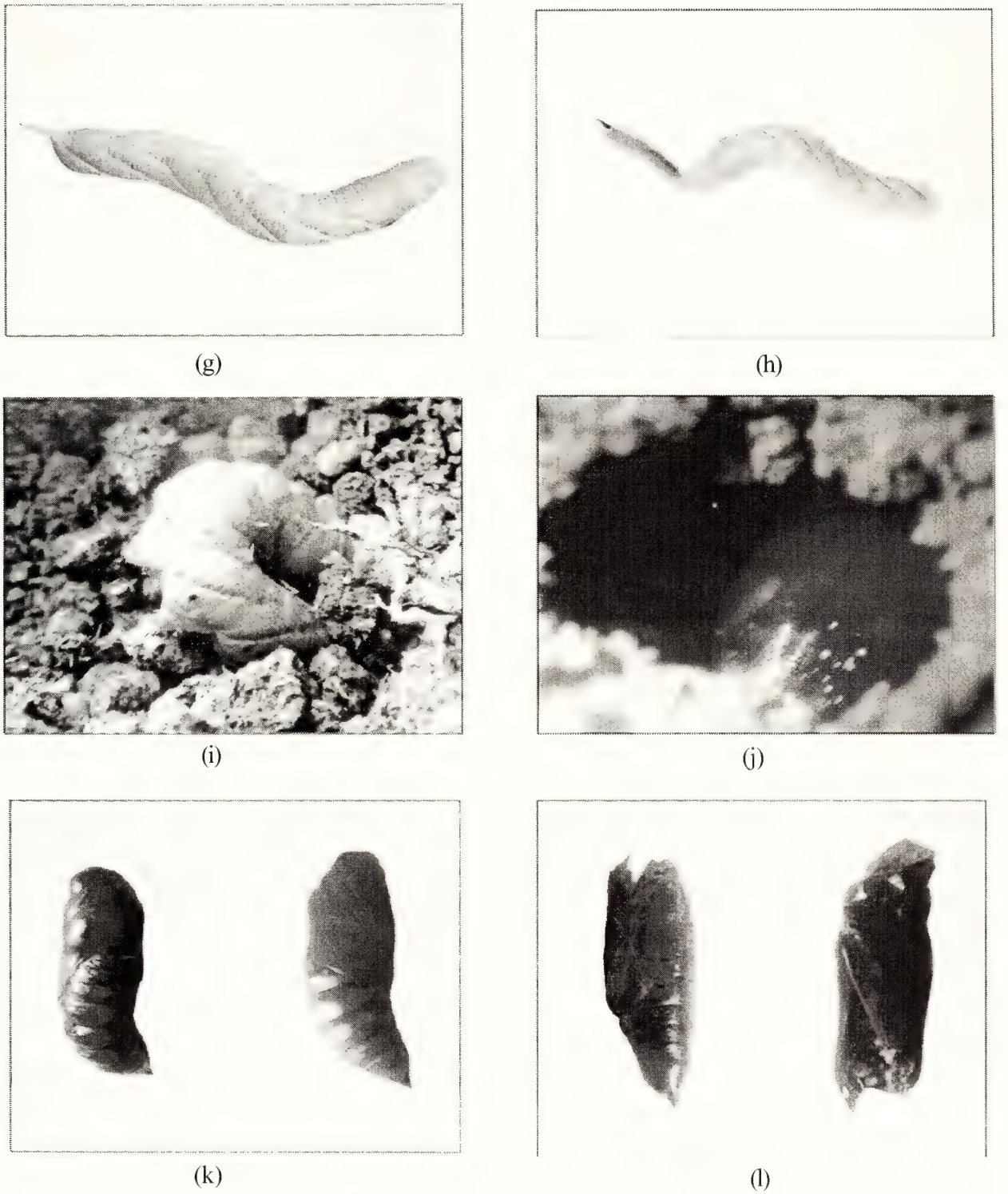
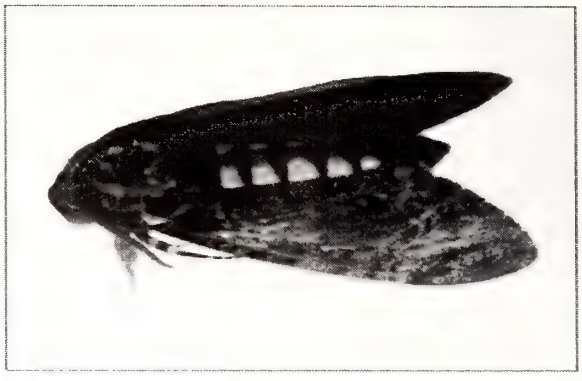
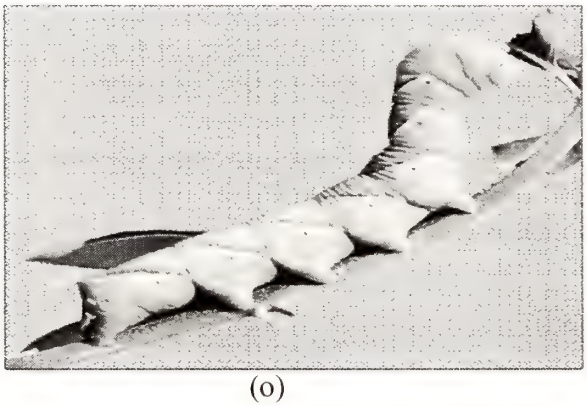


Fig. 1: (g) Fifth instar larva (h) Cannibalism (i) Fifth instar larva enterning in soil for pupation (j) Pupa in the earthen cell (k) Male and female pupae (l) Male and female adult emerging from pupae

(m)



(n)



(o)

(p)

Fig. 1: (m) Male adult (n) Female adult (o) Larva of *Acherontia styx* devouring leaves (p) Plant damaged by larva of *Acherontia styx*

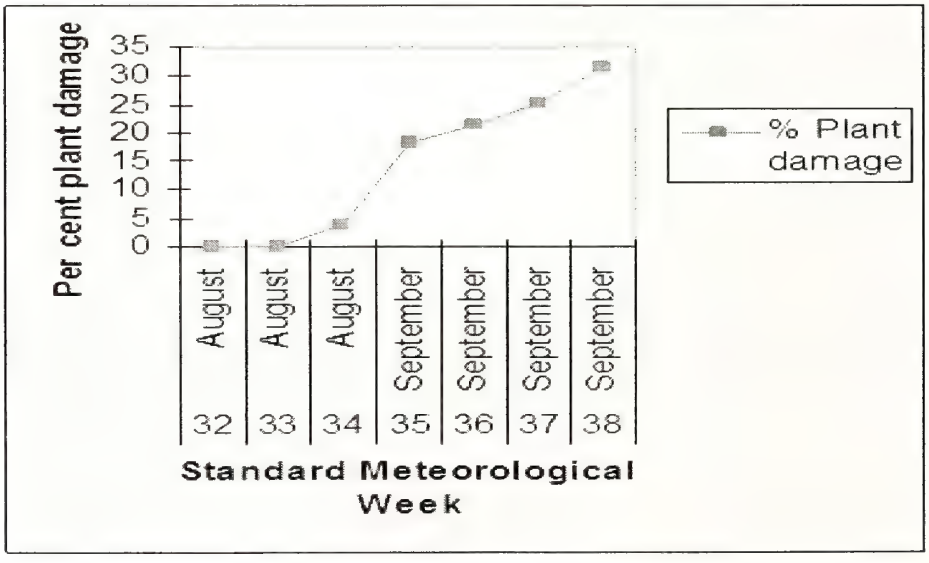


Fig. 2: Mean per cent damage of flowers caused by *Acherontia styx*

Table-1: Correlation coefficient between per cent damage of plant and weather parameters

Weather Parameters	*Acherontia larvae*
MaximumTemperature (°C)	0.840957*
MinimumTemperature (°C)	-0.43453
RelativeHumidity (%)	-0.85999
Rainfall (mm)	-0.55669

*Significant@ 0.05 probability

Table-2: Mean*(±SEM) size of egg to larval stage of *Acherontia styx* Westwood during 2004-06

Stage		Length (mm)		Width (mm)	
		Range	Mean*±SEM	Range	Mean*±SEM
Egg	Fresh	-	-	0.70-0.80	0.78±0.023
	Matured	-	-	0.90-0.95	0.91±0.018
Neonate larva	Young	3.50-4.00	3.80±0.097	0.35-0.50	0.45±0.018
	Full fed	4.50-5.00	4.58±0.129	0.60-0.70	0.67±0.032
	Dunk	2.50-3.00	2.59±0.052	0.20-0.28	0.23±0.013
1st instar larva	Young	9.00-12.00	10.40±0.91	1.00-1.50	1.19±0.13
	Full fed	18.00-22.00	20.00±0.71	2.00-2.40	2.30±0.082
	Dunk	2.90-3.00	2.96±0.045	0.25-0.30	0.29±0.012
2nd instar larva	Young	25.00-35.00	29.20±3.74	3.40-4.20	3.74±0.35
	Full fed	36.20-45.00	39.72±1.73	4.50-6.00	4.92±0.26
	Dunk	5.50-6.00	5.90±0.13	0.35-0.40	0.38±0.012
3rd instar larva	Young	50.00-55.00	53.75±1.60	6.30-6.50	6.41±0.051
	Full fed	57.00-60.00	58.00±0.66	6.60-7.00	6.63±0.088
	Dunk	6.50-7.00	6.85±0.13	0.45-0.50	0.49±0.012
4th instar larva	Young	61.20-64.40	62.85±0.85	7.10-7.40	7.24±0.102
	Full fed	65.00-73.00	68.50±1.10	7.60-8.00	7.84±0.14
	Dunk	7.60-8.00	7.90±0.10	0.52-0.60	.57±0.0066
5th instar larva	Young	74.20-75.50	74.73±0.30	8.20-8.70	8.52±0.12
	Full fed	77.20-82.00	78.52±0.98	9.00-10.00	9.55±0.47
	Dunk	8.00-8.50	8.29±0.052	0.70-0.80	0.74±0.046

*Mean of 10 individuals

Table-3: Life span (mean*± SEM) of Acherontia styx Westwood and size (mean*± SEM) of different developmental stages derived from observations during 2004-06

Parameters	Period Range			Size Range (mm)		
	Range	Mean* ± SEM	Length	Mean *± SEM	Width	Mean* ± SEM
Egg (Incubation)	02.00-04.00	03.18±0.33 (D)	-	-	00.70-0.95	00.82±0.089
Larval stage						
Neonate larvae	00.17-00.20	00.18±0.073 (M)	03.50-5.00	04.20±0.38	00.35-0.70	00.50±0.028
I instar	115.30-130.00	125.62±3.56 (H)	09.00-22.00	15.35±3.43	01.00-2.40	01.55±0.36
II instar	73.40-77.00	74.72±0.89 (H)	25.00-45.00	34.36±7.86	03.40-6.00	04.39±0.68
III instar	73.40-75.20	74.53±0.40 (H)	50.00-60.00	54.95±3.80	06.30-7.00	06.61±0.20
IV instar	44.30-49.00	46.44±0.84 (H)	61.20-73.00	67.29±2.80	07.10-8.00	07.43±0.14
V instar	68.00-78.30	73.43±0.30 (H)	74.20-82.00	78.59±2.53	08.20-10.00	08.14±0.30
Pre-pupa	78.00-86.00	81.43±1.90 (H)	40.00-41.00	40.20±0.26	05.00-5.30	05.04±0.046
Pupa	14.00-23.00	17.61±1.56 (D)	40.00-44.00	41.00±0.71	09.00-9.20	09.04±0.046
Developmental period (Larva & Pupa)-A	32.85-43.65	38.12±1.89 (D)	-	-	-	-
Adults						
Male	02.00-03.00	02.56±0.16 (D)	30.00-30.02	30.00±0.0047	34.00-35.02	34.90±0.21**
Female	03.00-05.00	03.76±0.39 (D)	37.05-38.00	37.72±0.24	39.00-40.02	39.90±0.21**
Pre mating	21.00-24.00	22.70±1.13 (H)	-	-	-	-
Mating	00.07-00.10	00.087±0.005 (M)	-	-	-	-
Pre-oviposition	11.00-15.00	12.45±1.53 (H)	-	-	-	-
Oviposition	24.00-36.00	27.60±4.73 (H)	-	-	-	-
Post oviposition	01.50-03.00	02.12±0.46 (D)	-	-	-	-
Total Life Span	39.00-52.00	44.44±3.17 (D)	-	-	-	-

*Mean of 10 individuals; ** : Width of wing span; D :Days; H : Hours; M : Minutes

Table-4: Mean duration (days)*±SEM of developmental stages and the total life span of *Acherontia styx* Westwood (First generation only) during 2004-06

Period of Study		Incubation Period	Larva	Pupa	Adult	Total Life Span
From	To					
27/08/04	10/10/04	2.91±0.23	19.83±0.66	14.43±0.14	1.990.045	39.10±0.037
25/08/05	03/10/05	2.90±0.22	19.99±0.51	14.32±0.031	1.99±0.048	39.14±0.051
01/09/06	12/10/06	2.92±0.20	19.75±0.19	14.43±0.12	1.99±0.052	38.92±0.212

*Mean of 10 individuals

Table-5: Mean duration (hours)*±SEM of feeding (F)and moulting (M) in larval instars of *Acherontia styx* Westwood (First generation only) during 2004-06

Year of Study/ Generation	First instar			Second instar			Third instar			Fourth instar			Fifth instar		
	F	M	T	F	M	T	F	M	T	F	M	T	F	PP	T
2004	120.10 ±0.95	9.10 ±1.00	129.20 ±1.95	66.00 ±0.68	08.00 ±0.90	74.00 ±1.58	68.00 ±0.91	06.40 ±0.57	74.40 ±1.48	34.40 ±1.22	10.00 ±0.75	44.40 ±1.97	68.35 ±0.98	78.00 ±0.21	146.35 ±1.19
2005	117.00 ±0.87	10.00 ±0.90	127.00 ±1.77	64.00 ±1.20	09.40 ±0.71	73.40 ±1.91	70.00 ±0.34	07.30 ±0.80	77.30 ±1.14	40.00 ±1.00	08.00 ±0.33	48.00 ±1.33	78.30 ±0.79	86.00 ±1.05	164.30 ±1.84
2006	121.30 ±0.91	10.30 ±1.15	122.00 ±2.06	68.30 ±1.00	08.30 ±0.83	75.00 ±1.83	66.40 ±1.12	07.20 ±0.25	74.00 ±1.37	38.00 ±0.84	09.30 ±0.49	47.30 ±1.33	75.79 ±0.89	79.30 ±0.72	154.70 ±1.61

*Mean of 10 individuals; F : Feeding duration; M : Moulting duration; PP : Prepupal period; T : Total hours of instar

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